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Demographic parameters of the diamondback moth, *Plutella xylostella* (Lep.: Plutellidae) on five rapeseed cultivars

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Abstract
The diamondback moth, *Plutella xylostella* (L.) (Lep.: Plutellidae) is one of the most destructive insect pests of cruciferous crops throughout the world. In this research, the demographic parameters of *P. xylostella* were studied on five rapeseed cultivars including Licord, Modena, Okapi, RGsoo3 and REGXkobra. The experiments were conducted in a growth chamber at temperature of 25 ± 1°C, 60 ± 5% RH and a photoperiod of 16: 8 (L: D) hr. The mortality of preimaginal stages differed from 47.65 to 65.75% on Modena and REGXkobra, respectively. The life expectancy of newly laid eggs and one-day-old adults of *P. xylostella* was estimated as 13.48, 4.90; 14.69, 10.84; 15.39, 7.72; 16.25, 12.23; 15.06 and 6.05 days on Licord, Modena, Okapi, RGsoo3 and REGXkobra, respectively. There was significant difference between net reproductive rates (R_o) of the cultivars. The highest value of R_o belonged to RGsoo3 (74.97 ± 7.99). The longest generation time was on Rgsoo3 while the shortest one belonged to the Modena. The intrinsic rate of natural increase (r_m) on Modena was significantly differed from other cultivars emphasizing that Modena was the most sensitive cultivar to the diamondback moth than the others.
Key words: *Plutella xylostella*, demography, life table, rapeseed cultivars

چکیده
شب‌پره‌ی پشت‌الماسی، *Plutella xylostella* (L.) (Lep.: Plutellidae) یکی از مخرب‌ترین آفات گیاهان چلیپاییان در سرتاسر دنیا است. در این تحقیق پارامترهای دموگرافیک این حشره روی پنج رقم کلزا شامل لیکورد، مودنا، اکاپی، RGsoo3 و REGXkobra بررسی شد. آزمایش‌ها در اطاقک رشد با دمای ۱ ± ۲۵ درجه‌ی سانتی‌گراد، رطوبت نسبی ۵ ± ۶۰ درصد و دوره نوری ۱۶ ساعت روشنایی و ۸ ساعت تاریکی انجام شد. مرگ و میر مراحل قبل از بلوغ از ۴۷/۶۵ درصد تا ۶۵/۷۵ درصد به ترتیب روی ارقام مودنا و REGXkobra متفاوت بود. امید به زندگی در تخم‌های تازه‌گذاشته‌شده و حشرات کامل در اولین روز ظهور روی ارقام لیکورد، مودنا، اکاپی، RGsoo3 و REGXkobra به ترتیب ۱۳/۴۸، ۴/۹۰؛ ۱۴/۶۹، ۱۰/۸۴؛ ۱۵/۳۹، ۷/۷۲؛ ۱۶/۲۵، ۱۲/۲۳؛ ۱۵/۰۶ و ۶/۰۵ روز تعیین شد. بین نرخ خالص تولید مثل (R_o) روی ارقام مختلف کلزا اختلاف معنی‌دار وجود داشت. بیشترین میزان نرخ خالص تولید مثل روی رقم RGsoo3 (۷/۹۹ ± ۷۴/۹۷) به دست آمد. طولانی‌ترین مدت طول هر نسل روی رقم RGsoo3 و کوتاه‌ترین طول نسل روی رقم مودنا مشاهده شد. بین نرخ ذاتی افزایش جمعیت (r_m) آفت روی رقم مودنا با سایر ارقام تفاوت معنی‌دار مشاهده شد که نشان می‌دهد رقم مودنا حساس‌ترین رقم به شب‌پره‌ی پشت‌الماسی است.
واژگان کلیدی: *Plutella xylostella*، دموگرافی، جدول زندگی، ارقام کلزا

Introduction

The diamondback moth (DBM), *Plutella xylostella* (L.) (Lep.: Plutellidae) is one of the most destructive insect pests of brassicaceous crops in the world. The global importance of DBM is reflected in estimated control costs of approximately US$ 1 billion per year (Talekar & Shelton, 1993; Verkerk & Wright, 1996). Absence of effective natural enemies, especially parasitoids, is believed to be a major cause of the DBM's pest status in new world (Lim, 1986). Although insecticides remain as the first defense against the DBM, but the evolution of resistance to pesticides has become a major problem (Shelton *et al*., 1991). Many species of brassicaceous crops are cultivated as vegetables and oil seed crops. Some weed species of cruciferous are fed by DBM in absence of their favored crop hosts and play important link in maintaining DBM populations (Talekar & Shelton, 1993; Begum *et al.*, 1996).

Population parameters are important to measure population growth capacity of a species under specified conditions. These parameters are also used as indices of population growth rates responding to selected conditions and as bioclimatic indices in assessing the potential of a pest population growth in a new area (Southwood & Henderson, 2000). The construction of life tables is appropriate to study the dynamics related to the population growth potential, also called demographic parameters (Carey, 1993, 2001; Southwood & Henderson, 2000). DBM demographic parameters estimates are also essential to understand the biological control programs. The intrinsic rate of natural increase (r_m) is a key demographic parameter useful to predict the population growth potential of an animal under a given environmental condition (Andrewartha & Birch, 1954; Ricklefs & Miller, 2000; Southwood & Henderson, 2000). The r_m value can be estimated from life table data under standardized laboratory condition (Southwood & Henderson, 2000). A number of extrinsic and intrinsic factors such as certain glucosinolates, cardenolides, plant volatiles, waxes, leaf morphology, as well as host plant nutritional quality or a combination of these factors have been shown to affect the r_m value and related demographic parameters (Gilbert & Raworth, 1996; Lee & Elliott, 1998; Syed & Abro, 2003; Sarfraz *et al*., 2006). Demographic studies have several applications: analyzing population stability and structure, estimating extinction probabilities, predicting life history evolution, predicting outbreak in pest species and examining the dynamics of colonizing or invading species (Vergas *et al*., 1997). The rapeseed, *Brassica napus* L. is the most important oil seed crop in Iran. Several cultivars of rapeseed are cultivated and attacked by DBM; however, its biology has not been studied in Iran. The current study is evaluating of the effect of 5 rapeseed cultivars upon the demographic parameters of the DBM. Study of life table parameters of DBM on different rapeseed cultivars is required to select the most appropriate cultivar in integrated crop management (ICM).

Materials and methods

Rearing methods and experimental conditions

The initial population of DBM was collected from the *Brassica* fields of Horticultural Research Center of University of Tehran in Karaj, during September 2006. Rapeseed cultivars included Licord, Modena, Okapi, RGsoo3 and REGXkobra were obtained from the Seed and Plant Improvement Institute in Karaj, Iran. The seeds were planted in a mixture of farm soil and compost (3: 1) in 20 cm diameter plastic pots. The rapeseed plants were used for experiments as soon as having 10 to 12 leaves. The stock culture of DBM was maintained in a growth chamber set at 25 ± 1°C, 60 ± 5% RH and a photoperiod of 16: 8 (L: D) hr. The population of DBM was reared on each cultivar for one generation before they were used in the experiments. In order to obtain the same aged eggs of DBM, host plant leaves were placed inside oviposition cages containing 8-10 pairs of both sexes of DBM. The oviposition cage were transparent and cubic Plexiglas's container (15 × 8 × 5 cm), with a fine nylon mesh installed on the top-side. After 12 hr, the host plant leaf was removed from the cage. A small cotton-wool wick soaked in 10% honey solution was placed in each oviposition cage as a source of carbohydrate for adults.

Survivorship, mortality and fecundity

All experiments were carried out in a growth chamber set at 25 ± 1°C, 60 ± 5% RH and 16: 8 (L: D) hr. The eggs of DBM were picked up from the surface of the host plant leaves using a small brush and placed individually in Petri dishes (8 × 1.5 cm) on a leaf of host plant. The petioles of detached leaves were inserted in water-soaked cotton-wool to preserve freshness. Lids of Petri dishes were covered with fine nylon mesh for aeration. At least 100 eggs of DBM were used to collect data on each rapeseed cultivars. The eggs were checked daily and their development stages were recorded. The larvae were fed on fresh host leaves provided from different cultivars. The leaves were replaced every day awaiting the larvae death or reaching the prepupal stage. The presence of exuviae was used to discriminate the larval instars. The regular checking of Petri dishes continued until the entire adults emerged or pupae died. The survival rate and development time were recorded for all immature stages. The adults sex ratio reared on the rapeseed cultivars was also determined. A fertility life table was constructed according to Birch (1948) and Carey (1993, 2001) based on the data resulted from the incubation period of the eggs, duration of nymphal instars, pre-oviposition period, age specific mortality/survivorship and fecundity.

Population growth parameters

For each cultivar, 20 newly emerged adult females and 20 males (n = 20 replications) were transferred to transparent plastic cages (15 × 8 × 5 cm). The host plant leaves were replaced with fresh ones. The number of eggs laid by each female was recorded daily and the recoding continued until death of the entire adult females.

Data analyses

Age-specific survival rates (l_x) and average number of female offspring (m_x) for each age interval (x) were used to construct age-specific fertility life tables. Using survivorship and fertility schedules, the demographic parameters of DBM including net reproduction rate (R_o), intrinsic rate of increase (r_m), finite rate of increase (λ), mean generation time (T), doubling time (DT) and life expectancy (e_x) were calculated. All terminology and formulae for computing demographic parameters are consistent with Carey (1993).

We used the jackknife method to estimate the variance for r_m and other reproduction and population parameters (Meyer *et al.*, 1986). The technique is based on the repeated recalculation of the required estimator and missing out each sample in turn (Maia *et al*., 2000). The jackknife pseudo-values for each rapeseed cultivar were subjected to the analysis of variance (ANOVA). The same procedures were used for the other parameters R_o, λ, T and DT. If significant differences were detected, multiple comparisons were made using the Student-Newman-Keuls (SNK) ($P < 0.05$). Statistical analysis was carried out using SPSS statistical software (SPSS, 2004). Data were checked for normality test prior to analyses.

Results

Survivorship, mortality and fecundity

The l_x of DBM on various rapeseed cultivars is given in fig. 1. The entire individuals in the cohort of DBM reared on Licord, Modena, Okapi, RGsoo3 and REGXkobra died at the age of 22, 27, 29, 35 and 24 days, respectively. The preimaginal mortality percentage of DBM reared on Licord, Modena, Okapi, RGsoo3 and REGXkobra was estimated to be 64.78, 47.65, 65.71, 49.29 and 65.75, respectively. In the same order, the e_x of DBM at the age of newly laid eggs (one-day-old) was 13.48, 14.69, 15.39, 16.25 and 15.06 days, and at the age of adult emergence was 4.9, 10.184, 7.722, 12.23 and 6.050 days on Licord, Modena, Okapi, RGsoo3, and REGXkobra (fig. 1).

The m_x of DBM on various cultivars of rapeseed is shown in fig. 1. The oviposition period of females was initiated on days 15, 12, 15, 16 and 16 on Licord, Modena, Okapi, RGsoo3 and REGXkobra, respectively. The peak of female oviposition was on days 15, 13, 16, 15 and 17 on Licord, Modena, Okapi, RGsoo3 and REGXkobra, correspondingly (fig. 1).

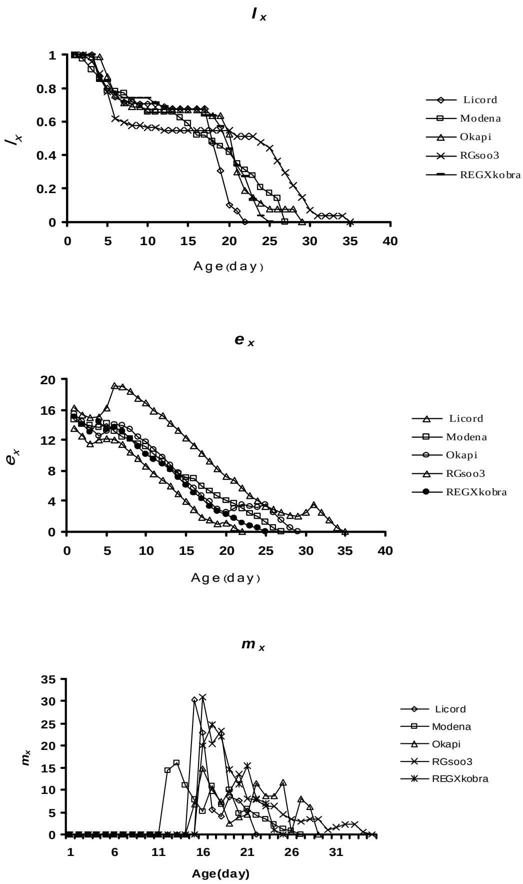

Figure 1. Age-specific survivorship (l_x), life expectancy (e_x) and age-specific fecundity (m_x) of *P. xylostella* on five rapeseed cultivars.

The gross fecundity rate (mean number of eggs/female/generation) was significantly different on various rapeseed cultivars (F = 3.605; df = 4, 90; P < 0.01) (table 1). The descending order of gross fecundity rate was estimated on the cultivars examined. The mean number of eggs per female per generation was highest on RGsoo3 (table 1). The net fecundity rates indicated significant differences among the cultivars (F = 5.701; df = 4, 88; P < 0.01) (table 1). The host plant cultivars, showed significant effects on the mean number of eggs per female per day (F = 5.969; df = 4, 90; P < 0.01) ranging from 13.74 to 28.32 (eggs/female/day) on

Okapi and REGXkobra, respectively (table 1). The sex ratio of DBM was affected by various cultivars too. The sex ratio of progeny was more female-biased on all cultivars (table 1).

Table 1. The reproductive parameters of *Plutella xylostella* on five rapeseed cultivars.

Parameters	Cultivars				
	Licord	**Modena**	**Okapi**	**Rgsoo3**	**REGXkobra**
Gross fecundity rate	$159.62 \pm 26.77^{b*}$ $14.93\text{-}528.12^{**}$ 159.62^{***}	200.11 ± 17.61 55.51-301.85 200.12	178.62 ± 24.80^{b} 87.195-453.40 178.62	285.83 ± 27.80^{a} 78.18-466.064 274.63	226.62 ± 24.25^{ab} 65.062-461.74 223.77
Net fecundity rate	65.94 ± 10.50^{b} 2.58-120.802 81.981	98.92 ± 11.20^{ab} 10.34-195.93 101.175	60.13 ± 10.59^{b} 12.88-184.47 60.175	130.39 ± 13.98^{a} 24.72-208.23 131.206	109.10 ± 13.51^{a} 15.28-271.168 109.34
Mean number of eggs/female/day	26.61 ± 4.46^{a} 2.48-88.02 26.604	14.29 ± 1.28^{b} 3.965-24.08 14.294	13.74 ± 1.907^{b} 7.67-34.87 13.740	15.87 ± 1.54^{b} 4.34-25.89 15.257	28.32 ± 3.03^{a} 6.108-57.71 27.971
Sex ratio (male:female)	1:1.08	1:1.08	1:1.23	1:1.15	1:1.15

The means followed by the different letters within rows are significantly different at the 0.05 level (ANOVA, SNK).
* Mean ± SE, ** Confidence intervals (C.I.), *** True value.

Population growth parameters

The *invitro* population growth parameters of DBM on the cultivars examined are shown in table 2. There were significant differences among the R_o on the cultivars (F = 5.408, df = 4, 88; P < 0.01). The highest amount of R_o was observed in RGsoo3. The r_m were also found to be significantly different in the cultivars (F = 4.829; df = 4, 91; P < 0.01). The r_m values ranged from 0.239 ± 0.009 to 0.287 ± 0.01 and the highest r_m value was recorded on Modena. Consequently, this rapeseed cultivar is a rather susceptible host for reproduction of DBM. The highest value of λ obtained on Modena that was significantly different from the other cultivars (F = 4.981; df = 4, 91; P < 0.01). The *DT* was also found to be significantly different within the cultivars examined (F = 3.44; df = 4, 91; P < 0.05) (table 2). Variation in *DT* is likely to be summarized into two groups (table 2). The *T* was also significantly differed on the cultivars (F = 34.34; df = 4, 91; P < 0.01). The DBM had longer generation time in REGXkobra and RGsoo3 than on the others (table 2).

Discussion

The present study demonstrated that the performance of DBM differed significantly on the five rapeseed cultivars and the results makes valuable data to determine the effect of the different cultivars on the herbivores, regarding to the insect-plant interactions. This study

Table 2. Population growth parameters of *P. xylostella* on five rapeseed cultivars.

Parameters	Cultivars														
	Licord			Modena			Okapi			Rgsoo3			REGXkobra		
	TC	JE	95% CL	TC	JE	95% CL	TC	JE	95% CL	TC	JE	95% CL	TC	JE	95% CL
Net reproduction rate (R_o)	45.45	36.28 ± 5.66^{b}	7.89-279.38	54.89	54.05 ± 5.89^{ab}	14.86-104.03	37.32	36.07 ± 6.38^{b}	7.13-111.76	73.57	74.97 ± 7.99^{a}	32.43-119.72	124.37	61.25 ± 8.08^{ab}	10.07-156.73
Intrinsic rate of increase (r_m)	0.2491	0.2396 ± 0.009^{b}	0.1879-0.3077	0.2872	0.2875 ± 0.01^{a}	0.2293-0.3927	0.2139	0.2506 ± 0.01^{b}	0.2025-0.3895	0.2419	0.2397 ± 0.07^{b}	0.1983-0.3012	0.2410	0.2394 ± 0.007^{b}	0.1920-0.3168
Finite rate of increase (λ)	1.28	1.27 ± 0.01^{b}	1.204-1.35	1.33	1.33 ± 0.01^{a}	1.25-1.47	1.23	1.28 ± 0.014^{b}	1.22-1.41	1.27	1.27 ± 0.008^{b}	1.21-1.34	1.27	1.27 ± 0.009^{b}	1.21-1.36
Doubling time (DT)	2.78	2.88 ± 0.10^{a}	2.17-3.45	2.41	2.40 ± 0.09^{b}	1.508-2.89	3.24	2.67 ± 0.18^{ab}	0.49-3.41	2.86	2.88 ± 0.08^{a}	2.15-3.37	2.86	2.89 ± 0.08^{a}	1.96-3.44
Mean generation time (T)	15.31	14.76 ± 0.20^{b}	13.75-17.78	13.94	13.88 ± 0.35^{b}	10.32-16.1009	16.92	13.94 ± 0.35^{b}	11.36-17.66	17.76	17.92 ± 0.31^{a}	16.56-20.27	17.23	17.44 ± 0.32^{a}	15.75-21.73

The means followed by the different letters within rows are significantly different at the 0.05 level (ANOVA, SNK). TC = True calculation, JE = Jackknife estimates (mean ± SE), CL = Confidence limits.

provides useful information on the effect of different rapeseed cultivars on the demographic parameters of DBM for the first time in Iran.

The life cycle of DBM varies considerably depending on various factors such as host plants and environmental conditions (Biever & Boldt, 1971; Ko & Fang, 1979; Ooi, 1986; Shelton *et al.*, 1991). Differences in the gross fecundity rates among rapeseed cultivars were found to be significant, showing that *P. xylostella* had host oviposition preference. The gross fecundity rates ranged from 159.62 eggs for Licord to 285.83 eggs for RGsoo3 (table 1). Syed & Abro (2003) reported that the mean fecundity of DBM on the varieties of *Brassica oleracea botrytis*, *B. oleracea capitata*, *B. oleracea italica*, *B. napus*, *B. campesteris*, *B. chinesis pekinesis* and *Raphanis sativus* was 212.3 ± 23.8, 190.0 ± 6.6, 97.7 ± 18.5, 82.0 ± 20.5, 118.7 ± 19, 83.3 ± 11.6 and 88.3 ± 20.0 eggs, respectively. The differences between the present study and their results can come from the physiological differences that depend on host plant and also their genetic differences as a result of geographical population origin. However, the ranges of fecundity in our study are to some extent in agreement with those of Syed & Abro (2003) reported on *B. oleracea botrytis* and *B. oleracea capitata*. The mean number of female lifetime fecundity was 139 on *Brassica juncea* (range 55 to 226) at 26°C in USA (Biever & Boldt, 1971), and 246 (range 95 to 602) at 20°C in Great Britain (Salinas, 1972). Liu *et al*. (1985) have also found that the mean fecundities on common kale were 300 ± 80, 143 ± 85 and 107 ± 47 eggs at 20, 25 and 30°C, respectively. However, direct comparison among these studies is difficult. Because factors such as host plant species, temperature and photoperiod strongly influence reproduction.

In the present study, the highest r_m value of DBM was obtained on Modena (0.2875). Salas *et al*. (1993) investigated the life table parameter of DBM on different host plants and the highest r_m value was obtained on cauliflower. Syed & Abro (2003) reported that DBM fed on cauliflower and cabbage showed higher r_m value (0.239 on cauliflower and 0.22 on cabbage), resulting from faster development (shorter generation time), higher survivorship and higher fecundity rates. The present findings are somewhat in agreement with those of Syed & Abro (2003).

The longest and shortest T values were obtained on the RGsoo3 (17.92 days) and Modena (13.88 days), respectively (table 2). Syed & Abro (2003) found that generation time was longest on *B. oleracea italica* (21.67 days) and shortest on *B. oleracea botrytis* (18.75 days), which are longer than those estimated for DBM in the current study. Liu *et al*. (1985) reported that the r_m and T values of the DBM on *B. oleracea* var. *capitata* were 0.2130 (female/female/days) and 15.5 (days), respectively. In the present work, the *DT* of DBM on Modena was shorter than those obtained on Licord, Okapi, RGsoo3 and REGXkobra. The R_o, T and r_m were determined to be 154.71, 21.93 and 0.2298, correspondingly in a study carried out by Wakisaka *et al*. (1992). Our finding indicated that, the highest R_o value of DBM was obtained on RGsoo3 (264.11 female/female/day). Syed & Abro (2003) reported that net reproduction rates of DBM were ranged from 31.79 to 89.71 on the *B. chiness pekinesis* and *B. oleracea botrytits*, respectively. They found that the R_o value of DBM on *B. napus* is 26.77, which was lower than the estimated amount resulted from the current study.

In conclusion, knowledge of how the quality of *B. napus* cultivars influences the demographic parameters of the DBM can help us understand the population dynamics and management of this insect. Furthermore, several life history parameters of DBM on experimental rapeseed cultivars could be used for potential antibiosis resistance. After laboratory studies, more attention should be paid to semi-filed and field experiments to obtain more applied results in field conditions. Plant cultivar traits such as toxicity, content of nutrients, feeding deterrents and physical characteristics may affect these parameters, which are necessary to be investigated in the future.

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