



Bottom-up effects of *Brassica* genotypes on performance of diamondback moth, *Plutella xylostella* (Lepidoptera: Plutellidae)

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ABSTRACT

The adverse effects of excessive application of insecticides is causing a renewed interest to find resistant host plants to insect pest. Herein, we attempted to elucidate the bottom-up effects of five canola cultivars (Elite, SLM₀₄₆, Star, NSA2, and RGS₀₀₃), four cabbage cultivars (Glob-Master, Green-Cornet, Red-Rocky and Mikado) and one cauliflower cultivar (S-Mila) on the life table and biological parameters of diamondback moth, *Plutella xylostella* L., (Lepidoptera: Plutellidae). The age-stage, two-sex life table theory was used to unveil biological differences of *P. xylostella* on the *Brassica* genotypes. All experiments were carried out in a laboratory at 25 ± 1 °C, 65 ± 5% and a photoperiod of 16:8 (L: D) hours. The development time of *P. xylostella* varied from 13.0 days (on Elite) to 17.4 days (on Red-Rocky). The highest and lowest of net reproductive rate (R_0) were recorded in NSA2 (27.0 offspring/individual) and Red-Rocky (4.7 offspring/individual), respectively. The intrinsic rate of increase (r) ranged from 0.072 day⁻¹ on Glob-Master to 0.169 day⁻¹ on Star. The mean generation time (T) value varied between 18.1 days on RGS₀₀₃ to 22.5 days on Red-Rocky. According to the results inferred from biological and demographical parameters studies, Glob-Master and SLM₀₄₆ were found as the resistant and susceptible cultivars, respectively. Revealing the resistance range of the studied *Brassica* cultivars and life history traits of *P. xylostella* on these cultivars provide insight into the eco-friendly control strategies of the pest through decreasing its damage rate and improving the condition for activity of natural enemies.

1. Introduction

The diamondback moth (DBM), *Plutella xylostella* (L.) (Lepidoptera: Plutellidae) has been well known worldwide for its capacity to rapidly become resistant to different classes of insecticides (Talekar and Shelton, 1993; Sarfraz et al., 2006). It is likely that DBM is attracted to its brassicaceous host plants by chemical (olfactory/gustatory) and physical (tactile/visual) stimuli (Bukovinszky et al., 2005). In most crop fields worldwide, brassicaceous crops are cultivated as vegetables (like *Brassica oleracea* subsp. *acephala* and *B. oleracea* sub sp. *capitata*) and non-vegetables such as canola (*B. napus*). Therefore, not only is the evolution of resistance to pesticides a major problem, but also the harmful effects of the residual toxicity on both humans and the environment have been considered in chemical-based control programs of

DBM (Shelton et al., 1993; Schellhorn et al., 2008).

Determining the life table parameters of a pest on different plants can deepen our understanding about pest-resistant varieties and facilitate efforts to decrease pesticide application. In addition, host plant resistance can be an effective approach for being replace broad-spectrum insecticides (Fathipour and Mirhosseini, 2017). The intrinsic rate of increase (r) of a pest species is a key growth parameter in evaluation of an insect's population under defined conditions such as climate and food resource (Southwood and Henderson, 2000; Soufbaf et al., 2012). Moreover, all of the biological events of insects can be summarized in r , which becomes it more suitable to unveil the differences of a host plant varieties. A tremendous body of knowledge is available about influencing of host plant on development, survival, reproduction and the life table parameters of insect pest (Ramachandran et al., 1998; Sarfraz

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et al., 2007; Golizadeh et al., 2009a; b; Soufbaf et al., 2010 a; b). The physical and volatile signals of host plants can influence the development and survival of larval stages as well as egg production of adults (Gols et al., 2009). So, by focusing on the different aspects of host plants, the suitable host plants can be recognized and exploited in a very safely manner in pest control programs.

Different phenotypes and cultivars of host plants may include different chemical and mechanical defenses, as well as avoidance/tolerance mechanisms affecting nourishing properties of them in facing with herbivorous insects. Therefore, the combination of these factors is an important approach that helps in the understanding of the performance of herbivore insects (Cornell and Hawkins, 2003; Agrawal, 2004). It seems that the defensive components (secondary compounds) referred to as Glucosinolates (hereafter GS) play a major role in brassicaceous plants (Fahey et al., 2001; Muller and Wittstock, 2005; Travers-Martin and Muller, 2008). In wild brassicaceous plants, the high level of GS affects negatively development time and adult body mass of insect pests (Gols et al., 2008). On the other hand, nitrogen as a primary plant metabolite can influence the biological parameters in a similar way to GS (Mattson, 1980; Johnson, 2008; Soufbaf et al., 2012). Knowing about influencing attributes of DBM host plants can provide a platform for designing a proper integrated crop management (ICM) program. Since DBM develops initial resistance to insecticides, this current study is an attempt toward finding eco-friendly approaches either to reduce or eliminate chemical control by providing non-chemical controlling approaches to be exploited. This study focuses on determining the life table parameters of DBM on the new cultivars of Brassicaceae including NSA2, Elite and Star, and their comparison with the other commercial cultivars.

2. Materials and methods

2.1. Plant and insect rearing

The *Brassica* genotypes used in the present study consisted of 10 *Brassica* genotypes including five cultivars of canola, *Brassica napus* (Elite, SLM₀₄₆, Star, NSA2, and RGS₀₀₃), four cultivars of cabbage, *Brassica oleracea* var. *capitata* (Glob-Master, Green-Cornet, Red-Rocky and Mikado), and one cultivar of cauliflower, *B. oleracea* var. *botrytis* (S-Mila). The canola cultivars were planted in the greenhouse of Tarbiat Modares University (35° 44' N, 51° 09' E, 1273.46 m), Tehran, Iran, and when they reached 10 to 12 leaves (about 6 weeks after planting), were included in the experiments. The cabbage and cauliflower seeds were sown in transparent boxes (30 × 50 × 30 cm) in the greenhouse and when the plants reached 5 to 8 leaves, each plant was transferred individually into a pot. All seeds were obtained from the Seed and Plant Improvement Institute, Karaj, Iran. During the experiments, neither fertilizers nor pesticides were applied.

The DBM larvae and pupae were collected from the cabbage field of the University of Tehran (located in Karaj, Iran). To obtain a pathogen and parasitoid free stock, the colony was established just with adult individuals. The DBMs were reared on Opera, a cultivar of canola, in a growth chamber set at 25 ± 1 °C, 65 ± 5% and a photoperiod of 16:8 (L: D) hours. The F2 generation of DBM was used in all experiments.

2.2. Experiment

Demographic parameters of DBM were studied on the 10 *Brassica* genotypes in a growth chamber set at 25 ± 1 °C, 65 ± 5% and a photoperiod of 16:8 (L: D) hours. The experiment was arranged in a complete randomized design (CRD). More than 100 pairs of *P. xylostella* were transferred into the oviposition cages (Plexiglas containers of 14 cm in diameter and 19 cm in depth, with the tops covered with a fine mesh net). In each container, one young leaf with a small cotton wick soaked in water was used as the oviposition substrate and changed daily. When DBM passed two generations on each cultivar, about 100

eggs of DBM were gathered randomly with a fine camel's hair brush. The eggs were individually transferred into plastic containers (diameter 8 cm, depth 1 cm) with a hole in the top covered by a fine mesh net for ventilation. There was a young leaf of each *Brassica* host plant inside the container, and end of its stem was covered with a small wet cotton, which was changed daily.

The eggs and other immature stages of the third laboratory generation were monitored daily for molting and mortality. The larval instars were identified by measuring the head capsules and their head color (Harcourt, 1957). The larval head capsule size increases with each molting, which can be used in larval instar determination. As which, color of the head varies in the different instars, exploiting profusely in differentiation of the larval stages (black, dark-brown, brown and green colors confirm the first, second, third and forth instars of *P. xylostella*, respectively (Talekar and Shelton, 1993).

Within 24 h of adult emergence, individuals were sexed. The males of *P. xylostella* have claspers at the end of abdomen and the females have some branches of hair and a tubular ovipositor (Harcourt, 1957). Then, a pair of *P. xylostella* was transferred into the new oviposition cage and kept until death. The adults were provided with water. The number of laid eggs and the rate of their mortality were recorded daily in all cages. If a male died, a newly emerged male (< 24 h old) was replaced. Accordingly, the pre-oviposition, oviposition and post-oviposition periods were determined.

2.3. Statistical analysis

All data were tested for normality using the Kolmogorov-Smirnov's test before they are analyzed using the analysis of variance (ANOVA) (PROC GLM, SAS Institute, 2003). Mean separations were conducted using the Duncan's Multiple Range test ($\alpha = 0.05$), if significance differences were detected. The life table parameters including the net reproductive rate (R_0), intrinsic rate of increase (r), finite rate of increase (λ) and mean generation time (T) were calculated using the formulae suggested by Carey (1993). The raw data of the life history of all individuals (males, females and those died before the adult stage) were analyzed by the age-stage, two-sex life table theory (Chi and Liu, 1985; Chi, 1988). Data analysis and population parameters (R_0 , r , λ , T) data were calculated by using the TWSEX-MSChart program (Chi, 2016). The standard errors of the population parameters were estimated by using the bootstrap procedure (Huang and Chi, 2013; Khanamani et al., 2013) and bootstrap values were compared using paired-bootstrap procedure (Riahi et al., 2016; Khanamani et al., 2017). The two-sex life table bootstrap-values of the *P. xylostella* on different host plants were compared using the paired-bootstrap procedure.

Nested analysis is useful as a mixed-method strategy for comparative research (Lieberman, 2005). A nested *t*-test is the appropriate hypothesis test when there is one measurement variable and two or more nominal variables (Here, there were two different groups including the canola group and the cabbage + cauliflower group) (Storm, 2010). Formerly, this analysis is the abundant application in genetic research; however there is no data on its application for comparing the biological parameters.

Biological characteristics of DBM such as immature stage, survival of immature stage, adult longevity, daily fecundity, total fecundity, oviposition period and demographic parameters including R_0 , r , λ , T and sex ratio (female/female + male) were used for nested analysis for classification of the cultivars tested. The cultivars were classified into two groups, canola and cabbage + cauliflower. A normality test, ANOVA, and nested analysis were performed by SPSS software (SPSS 16, 2007).

Table 1
Mean \pm SE duration of different developmental stages of *Plutella xylostella* on different *Brassica* cultivars.

Cultivar	Incubation (Day)	Instar 1 (Day)	Instar 2 (Day)	Instar 3 (Day)	Instar4 (Day)	Total larvae (Day)	Pupa (Day)	Total (Day)
Canola								
Star	B2.33 \pm 0.07ab	A3.27 \pm 0.09a	B1.68 \pm 0.06ab	C1.37 \pm 0.06bc	B1.44 \pm 0.08bc	A14.70 \pm 0.21b	B4.56 \pm 0.08b	A14.70 \pm 0.21b
Elite	B2.69 \pm 0.09ab	A3.18 \pm 0.11a	B1.59 \pm 0.08ab	B1.71 \pm 0.09bc	B1.42 \pm 0.07bc	B12.95 \pm 0.41c	B4.63 \pm 0.07b	B12.96 \pm 0.42c
NSA2	A3.14 \pm 0.07a	A3.53 \pm 0.15a	B1.71 \pm 0.08ab	B2.00 \pm 0.22b	AB1.66 \pm 0.07bc	AB13.67 \pm 0.49bc	A7.71 \pm 0.09a	B13.67 \pm 0.50bc
SLM ₀₄₆	A3.19 \pm 0.07a	B2.42 \pm 0.09bc	A2.22 \pm 0.10a	A2.19 \pm 0.11a	A1.72 \pm 0.09bc	AB13.71 \pm 0.41b	B4.43 \pm 0.12b	B13.71 \pm 0.42bc
RGS ₀₀₃	AB3.00 \pm 0.07a	B2.27 \pm 0.09c	A2.12 \pm 0.13ab	A2.26 \pm 0.09a	A1.89 \pm 0.08ab	AB14.33 \pm 0.37b	B3.98 \pm 0.10b	AB14.33 \pm 0.38b
Cabbage and Cauliflower								
Glob-Master	A3.08 \pm 0.09a	A3.75 \pm 0.17a	A1.90 \pm 0.09ab	A2.23 \pm 0.13a	A2.12 \pm 0.09ab	A17.48 \pm 0.29a	A4.79 \pm 0.09b	A17.40 \pm 0.29a
Mikado	A2.95 \pm 0.08a	B2.92 \pm 0.15b	A1.79 \pm 0.09ab	A2.07 \pm 0.10ab	A2.05 \pm 0.10ab	AB16.29 \pm 0.28ab	A4.93 \pm 0.08b	B16.29 \pm 0.29ab
Green-Cornet	A3.09 \pm 0.06a	B3.03 \pm 0.08b	AB1.59 \pm 0.08b	A2.53 \pm 0.14a	A2.31 \pm 0.11ab	A17.04 \pm 0.21a	A4.55 \pm 0.11b	A17.04 \pm 0.21a
Red-Rocky	A2.97 \pm 0.09a	AB3.49 \pm 0.20a	A2.00 \pm 0.12ab	A2.23 \pm 0.22ab	A2.29 \pm 0.13ab	A17.40 \pm 0.30a	A4.43 \pm 0.18c	A17.40 \pm 0.30a
S-Mila	A3.04 \pm 0.07a	B2.88 \pm 0.13b	A1.86 \pm 0.22ab	AB1.73 \pm 0.09b	AB1.94 \pm 0.11ab	B15.79 \pm 0.29ab	A4.43 \pm 0.11b	B15.79 \pm 0.29ab

The means marked with the same lower case letters within the same column are not significantly different ($\alpha = 0.05$, Duncan's multiple range test).

Means marked with the same capital letter within the same column of each host plant (canola and cabbage + cauliflower) are not different significantly ($\alpha = 0.05$, Duncan's multiple range test).

3. Results

3.1. Developmental time

The effects of the different *Brassica* genotypes on the duration of the developmental stages of *P. xylostella* is presented in Table 1. As shown, while there is significant difference among the embryonic developments of *P. xylostella* on different canola cultivars ($F = 22.12$, $df = 4,495$, $P < 0.01$), no significant difference was found in the incubation periods of *P. xylostella* on different cabbage + cauliflower cultivars ($F = 0.73$, $df = 4,271$, $P > 0.05$).

The durations of the other developmental stages were affected by different *Brassica* cultivars tested. The lowest and highest developmental times of the *P. xylostella* were observed on Elite (12.9 ± 0.42 days) and Star (14.7 ± 0.21 days) ($F = 2.53$, $df = 4,486$, $P < 0.05$) from the canola group, and S-Mila (15.79 ± 0.29 days) and Glob-Master (17.40 ± 0.29 day) (similarly Red-Rocky) from cabbage + cauliflower, respectively ($F = 6.43$, $df = 4,270$, $P < 0.01$). Among all tested genotypes, Elite showed the lowest and Glob-Master and Red-Rocky showed the highest development times ($F = 16.57$, $df = 9,756$, $P < 0.01$). In total, *P. xylostella* reared on the cabbage + cauliflower cultivars had longer development time compared with canola cultivars (Table 1).

The age-stage specific survival rates (s_{xj}) of *P. xylostella* (Fig. 1) show the survivorship and stage differentiation as well as the variable developmental rate. The mean number of offspring produced by *P. xylostella* individuals of the age x and stage j per day is shown with the age-stage specific fecundity (f_{xj}) in Fig. 2. The start of oviposition of the first female on Star, Elite, NSA2, SLM₀₄₆, RGS₀₀₃, Glob-Master, Mikado, Green-Cornet, Red-Rocky and S-Mila occurred at the age 13, 14, 15, 15, 15, 18, 15, 15, 16 and 14, respectively. The highest daily fecundity of *P. xylostella* on the above-mentioned cultivars was 15.46, 16.27, 12.70, 20.00, 8.63, 6.68, 11.91, 12.00, 9.67 and 10.75 eggs, respectively, which occurred at the age 22, 16, 17, 26, 16, 21, 17, 21, 25 and 14 days, respectively. The age-specific survival rates (l_x) at age of adult emergence of *P. xylostella* on the above-mentioned cultivars were 0.81, 0.70, 0.79, 0.89, 0.51, 0.66, 0.56, 0.56, 0.96, and 0.69, respectively (Fig. 2). The l_x curves of the pest for the ten cultivars (Fig. 2) in general, showed a similar pattern with high mortality occurred during last 5 d. The mortality was high particularly in the first-instar larvae then declining slowly until the adult stage in which the high mortality again occurred during the last 5 d of the life span.

3.2. Adult longevity, oviposition period and fecundity

The adult longevity, oviposition period, fecundity and sex ratio of *P.*

xylostella on the studied *Brassica* genotypes are given in Table 2. Adult longevity was significantly different in the host plants tested ($F = 8.75$, $df = 4,125$, $P < 0.01$). Among canola host cultivars, the shortest (6.73 ± 0.36 days) and longest (11.28 ± 0.50 days) adult longevity were observed on RGS₀₀₃ and NSA2, respectively ($F = 8.75$, $df = 4, 125$, $P < 0.01$). In the cabbage + cauliflower group, the shortest and longest adult longevity of *P. xylostella* were found on Mikado and Glob-Master, respectively (4.32 ± 0.56 and 7.30 ± 0.34 days, respectively) ($F = 6.47$, $df = 4, 94$, $P < 0.01$).

Among all host plants, the pre-oviposition period of *P. xylostella* was not significantly different except in RGS₀₀₃ ($F = 3.01$, $df = 9,209$, $P < 0.05$). The oviposition period of *P. xylostella* was significantly different among all *Brassica* cultivars ($F = 9.65$, $df = 9,209$, $P < 0.01$) and the highest value of oviposition period was observed on Elite (5.17 ± 0.064 days) from canola and S-Mila (3.44 ± 0.33 days) from cabbage + cauliflower groups. The results also showed that post-oviposition period of *P. xylostella* was not affected significantly by different *Brassica* cultivars ($F = 0.76$, $df = 9,113$, $P > 0.05$).

The total fecundity of *P. xylostella* was also affected by the different *Brassica* cultivars (canola, cabbage and cauliflower) ($F = 9.90$, $df = 9,178$, $P < 0.01$). Means of the total number of offspring per female ranged from 88.81 on NSA2 to 24.00 on Glob-Master (Table 2). The number of offspring per female per day was also significantly different among the *Brassica* cultivars ($F = 7.43$, $df = 9,168$, $P < 0.01$) and the values ranged from 8.52 for RGS₀₀₃ to 27.73 for SLM₀₄₆ (Table 2). The lowest and highest value of sex ratio (percentage of females) was 43% and 56% for RGS₀₀₃ and NSA2, respectively.

3.3. Population parameters of *P. xylostella*

The population parameters of *P. xylostella* on the various *Brassica* cultivars are shown in Table 3. The R_0 values of *P. xylostella* reared on various plant cultivars were significantly different. The means of R_0 ranged from 5.04 offspring/individual on Green-Cornet to 26.96 offspring/individual on NSA2.

The intrinsic rate of increase (r) was significantly different on the studied genotypes. The lowest (0.065 day^{-1}) and highest (0.169 day^{-1}) values of intrinsic rate of increase were observed on Red-Rocky and Star, respectively (Table 3). As which, the maximum value of the finite rate of increase (λ) was observed on Star from the canola group (Table 3). The mean range of λ was from 1.185 day^{-1} on Star to 1.06 day^{-1} on Red-Rocky. In comparing all cultivars studied, Red-Rocky (22.52 days) and RGS₀₀₃ (18.06 days) showed the longest and shortest mean generation time (T), respectively (Table 3).

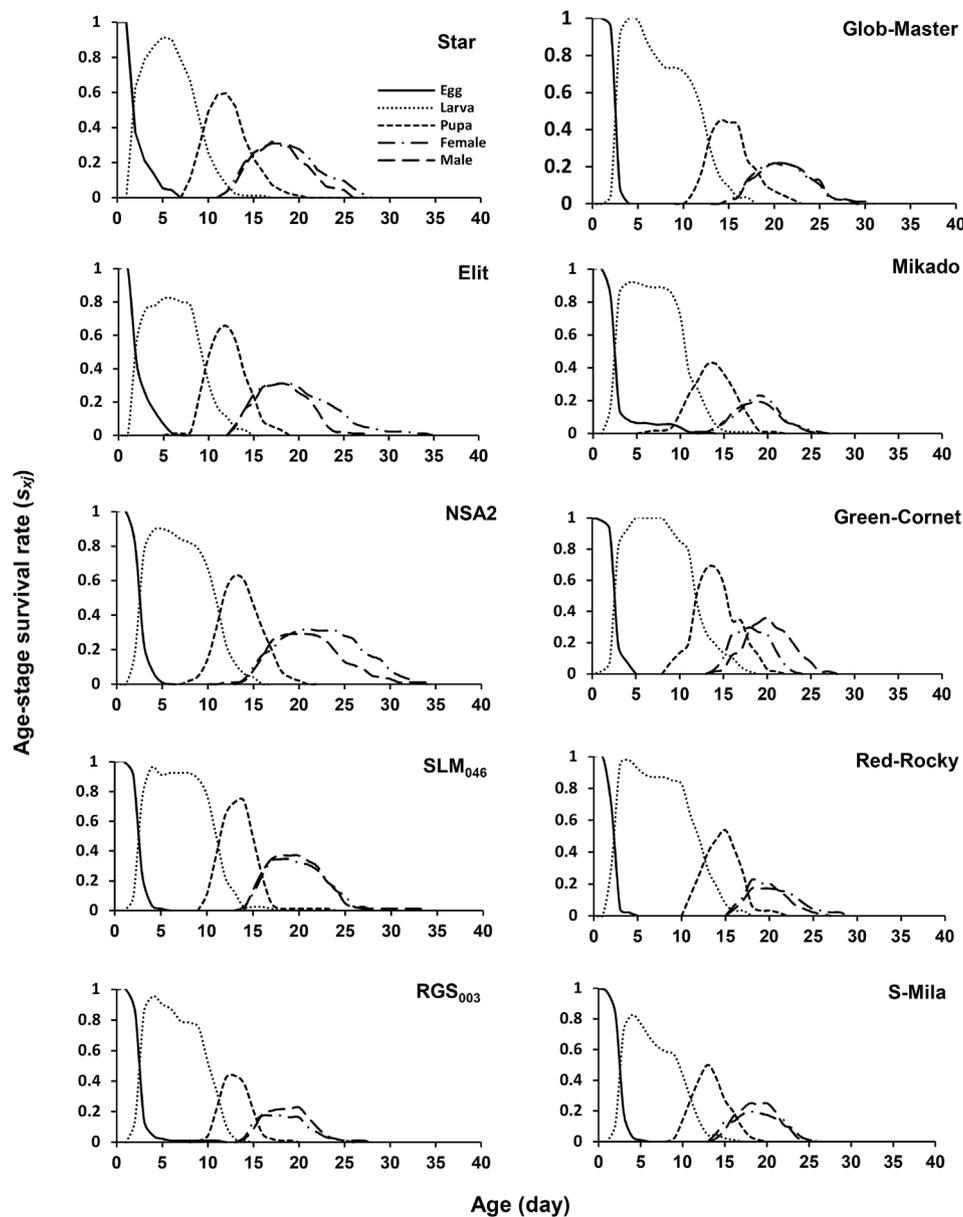


Fig. 1. The Age-stage survival rate (s_{xj}) of *Plutella xylostella* on different *Brassica* cultivars.

4. Discussion

Biological and demographic parameters of insect species are usually depending on the host plants species they are feeding (Southwood and Henderson, 2000; Soufbaf et al., 2010a). The development, survival and reproductive rates of different insect species feeding on various host plants are varied and influenced by factors that determine the susceptibility or resistance of host plants (Sarfranz et al., 2007).

In the present study, the developmental time of *P. xylostella* was found to vary on the different *Brassica* host plants, though the differences among some of the host plants were very low. The preimaginal development of *P. xylostella* was significantly faster on Elite compared with the other cultivars of canola. This variation in development times can be related to the variations in the plant quality and phagostimulant compounds (Syed and Abro, 2003; Ebrahimi et al., 2008; Sarfranz et al., 2007; Soufbaf et al., 2010a). Gols et al. (2008) indicating the effect of different levels of primary and secondary metabolites on development time in specialist herbivores; for example, the high concentrations of GS as a defense compound cause a longer development time. On the other hand, the high level of nitrogen in leaves causes an acceleration in the

development time of herbivorous insects (Nikooei et al., 2015).

Some discrepancies were found between results of the current study and findings of other researchers. For instances, while our findings regarding the adult longevity were close to outcomes documented by Nikooei et al. (2015), they had some differences with those reported by Golizadeh et al. (2009a,b), Soufbaf et al. (2010a) and Fathi et al. (2011). It can be stemming from the characteristics of the specific populations of both *P. xylostella* and Brassicaceae cultivars or may be related to the difference in culturing and planting conditions such as soil fertility (Lu et al., 2004; Badenes-Perez et al., 2005; Sarfranz et al., 2009) or temperature (Chhagan and Stevens, 2007; Yadav and Chang, 2014).

The observed total fecundity in the present study ranged from 24.00 to 88.81 eggs per female, which was substantially lower than that found in previous studies (Ebrahimi et al., 2008; Golizadeh et al., 2009a; Saeed et al., 2010; Soufbaf et al., 2010a; Fathi et al., 2011). In all of the previous studies, 10% honey solution was used for adult feeding, while in the present study, adults were fed only by water. It seems that honey (as carbohydrate source) has main role in the reproduction of *P. xylostella* like that seen in *Spodoptera exigua* (Hübner) (Lepidoptera: Noctuidae) (Tisdale and Sappington, 2001). On the other hand,

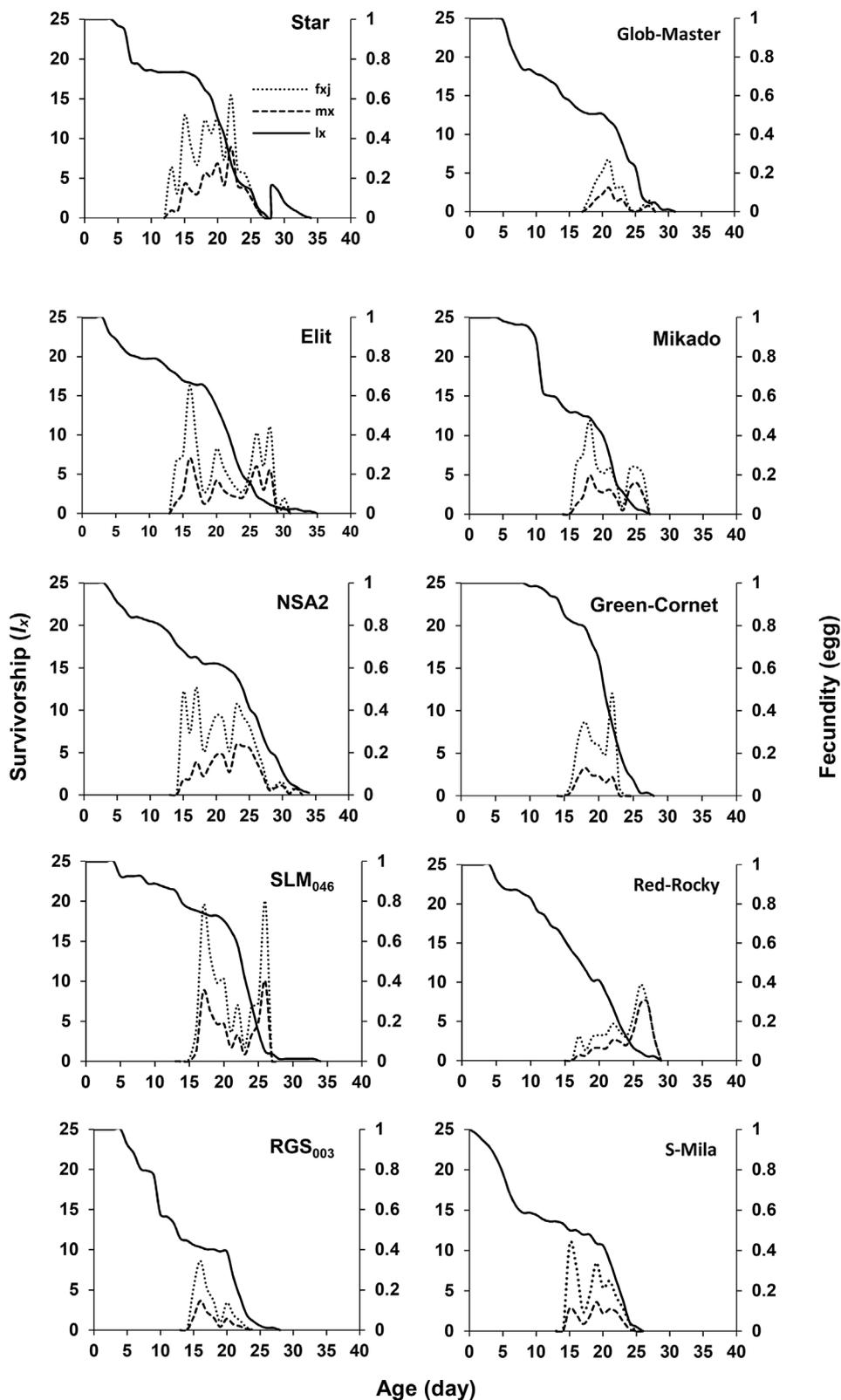


Fig. 2. The Age specific survivorship (l_x), age-stage specific fecundity of female (f_{xj}) (offspring) and age specific fecundity (m_x) of *Plutella xylostella* on different *Brassica* cultivars.

nitrogen/sulfur affects interactions of insect-Brassicaceous plants through affecting the GS content.

Among the *Brassica* genotypes under investigation, SLM₀₄₆ showed high susceptibility to *P. xylostella*. The high adult longevity and fecundity as which the high growth parameters value of *P. xylostella* on

SLM₀₄₆ showed that this pest has been able to complete well its life cycle on SLM₀₄₆. By contrast, RGS₀₀₃ as canola cultivar revealed high resistance to *P. xylostella*. These outcomes are inconsistent with findings of other researchers regarding high susceptibility of SLM₀₄₆ and inferior hosting property of RGS₀₀₃ to *P. xylostella* (Soufbaq et al., 2010a;

Table 2
Mean ± SE pre-, post- and oviposition periods, sex ratio and fecundity of *Plutella xylostella* on different *Brassica* cultivars.

Cultivar	Pre-oviposition period (Day)	Oviposition period (Day)	Post-oviposition period (Day)	Adult longevity (Day)	Fecundity (Eggs)		Sex Ratio (%)
					Daily	Total	
Canola							
Star	A3.03 ± 0.32a	A3.72 ± 0.46b	A1.5 ± 0.10a	B8.31 ± 0.47b	A26.85 ± 2.65a	A84.80 ± 8.95a	52
Elite	A2.93 ± 0.27a	AB5.17 ± 0.64a	A1.5 ± 0.10a	AB9.53 ± 0.74ab	BC12.28 ± 2.25bc	AB67.14 ± 8.98ab	55
NSA2	A2.78 ± 0.31a	B1.00 ± 0.52c	A1.08 ± 0.15a	A11.28 ± 0.50a	BC13.27 ± 2.13bc	A88.81 ± 13.56a	56
SLM ₀₄₆	AB2.21 ± 0.25ab	A3.92 ± 0.36b	A1.64 ± 0.17a	B8.29 ± 0.31b	A27.73 ± 3.36a	A88.77 ± 8.68a	49
RGS ₀₀₃	B1.13 ± 0.13b	A3.93 ± 0.46b	A1.14 ± 0.25a	BC6.73 ± 0.36bc	C8.52 ± 1.20bc	B29.57 ± 4.41bc	43
Cabbage and Cauliflower							
Glob-Master	A2.75 ± 0.28a	AB2.70 ± 0.28bc	A1.50 ± 0.17a	A7.30 ± 0.34b	B9.33 ± 1.42c	AB24.00 ± 3.23bc	51
Mikado	A2.21 ± 0.33ab	AB2.54 ± 0.27bc	A1.21 ± 0.15a	B4.32 ± 0.56c	A19.21 ± 3.00ab	A38.17 ± 5.96ab	50
Green-Cornet	A1.93 ± 0.22ab	AB3.20 ± 0.41bc	A1.13 ± 0.19a	AB6.27 ± 0.39bc	AB15.70 ± 2.28bc	A39.25 ± 5.36ab	53
Red-Rocky	A2.08 ± 0.49ab	B2.50 ± 0.45bc	A1.58 ± 0.29a	AB6.17 ± 0.63bc	AB14.53 ± 3.67bc	AB31.77 ± 8.71bc	46
S-Mila	A2.22 ± 0.29ab	A3.44 ± 0.33bc	A1.22 ± 0.21a	A6.89 ± 0.43bc	AB12.59 ± 1.84bc	A37.53 ± 5.46ab	44

Means marked with the same lower case letters within the same column are not significantly different ($\alpha = 0.05$, Duncan's multiple range test). Means marked with the same capital letters within the same column of each host plant (canola and cabbage + cauliflower) are not significantly different ($\alpha = 0.05$, Duncan's multiple range test).

Nikooei et al., 2015). Similar results are existing relating the hosting properties of these cultivars to other insect pests like cabbage aphid, *Brevicoryne brassicae*, *S. exigua* etc. (Goodarzi et al., 2015; Fathipour et al., 2018; Karami et al., 2018). Also, RGS₀₀₃ has showed that can be used as a proper cultivar in the integrated pest management programs due to its positive interaction with alternate trophic levels (Soufbaef et al., 2010a, 2012). However, in comparing with other studies on bottom up effects of canola cultivars on different pests, sometimes a clear discrepancy was found regarding hosting features of the cultivars studied here. For instances, in the current study RGS₀₀₃ showed high resistance to *P. xylostella* while Karimi et al. (2012) reported its high susceptibility to *H. arimgera* damage. These results show that a host cultivar may play different role in facing with various pests and exhibit different resistance level, suggesting we should have different strategies in using host plant cultivars.

It is well known that *r* is an important parameter of population dynamics (Varley and Gradwell, 1970; Salas et al., 1993). There are many life table studies in which the effect of different Brassicaceae on overall performance of the *P. xylostella* has been evaluated (Sarfranz et al., 2007; Golizadeh et al., 2009a; b; Soufbaef et al., 2010a). The estimated *r* values of *P. xylostella* in this study ranged from 0.065 day⁻¹ on the cabbage var. Red-Rocky to 0.169 day⁻¹ on the canola var. Star. Our *r* values were lower than those recorded previously (e.g. 0.16 day⁻¹ on cauliflower by Salas et al. (1993), and 0.22 day⁻¹ on cabbage and 0.24 day⁻¹ on cauliflower by Syed and Abro (2003). Similarly, Ebrahimi et al. (2008), Golizadeh et al. (2009a, b), Saeed et al. (2010), Soufbaef et al. (2010a) and Fathi et al. (2011) found higher *r* values than

ours. These differences could be attributed to the type of the *Brassica* cultivar as which to the strain of *P. xylostella* like what mentioned above. The significant differences in population parameters among allopatric populations of a pest have been documented previously by many researchers (Huang and Chi, 2012; Bagheri et al., 2016). Although, other studies on *P. xylostella* were analyzed as female-based life tables in which only female population is included in analyses and male population and their mortality are ignored.

In this study, the *R*₀ value on Red-Rocky was lower than that estimated on the other tested cultivars which is presumably due to differences in nutritional quality of the food sources that were taken in immature stages. The quality of host plant is the major determinant factor of the fecundity of herbivorous insects (Awmack and Leather, 2002). Mean generation time (*T*) was longer on NSA2 and Red-Rocky than those estimated on the other cultivars. On the one hand, a shorter *T* allows more generations on a host, while prolonged *T* could increase the chance of natural enemies to predate or parasite the pest (Gols et al., 2008, 2009).

5. In conclusion

The key factor in an integrated crop management (ICM) program is to know the range of resistance in different plant cultivars, population growth potential of a pest, and its life history on a crop that helps in the monitoring of the pest and in selecting the proper less pest-damaged cultivars (Sarfranz and Keddie, 2005; Schellhorn et al., 2008; Sarfranz et al., 2007). In summary, we found significant differences in the

Table 3
Life table (population) parameters of *Plutella xylostella* on different *Brassica* cultivars.

Cultivar	<i>R</i> ₀ (offspring/individual)	<i>r</i> (day ⁻¹)	λ (day ⁻¹)	<i>T</i> (day)
Canola				
Star	25.21 ± 4.56a	0.169 ± 0.012a	1.185 ± 0.14a	18.92 ± 0.56b
Elite	20.71 ± 4.27b	0.158 ± 0.013a	1.171 ± 0.016a	19.06 ± 0.70b
NSA2	26.96 ± 5.25a	0.153 ± 0.011a	1.165 ± 0.014a	21.44 ± 0.63a
SLM ₀₄₆	24.30 ± 4.79a	0.160 ± 0.011a	1.174 ± 0.013a	19.79 ± 0.41b
RGS ₀₀₃	4.70 ± 1.30b	0.08 ± 0.016bcd	1.087 ± 0.017bcd	18.06 ± 0.49b
Cabbage and Cauliflower				
Glob-Master	5.04 ± 1.21b	0.072 ± 0.011cd	1.074 ± 0.012cd	22.01 ± 0.57a
Mikado	8.39 ± 1.88b	0.106 ± 0.012bc	1.112 ± 0.014bc	19.79 ± 0.41b
Green-Cornet	9.49 ± 2.38b	0.113 ± 0.013b	1.119 ± 0.014b	19.61 ± 0.40b
Red-Rocky	4.68 ± 1.64b	0.065 ± 0.016d	1.06 ± 0.017d	22.52 ± 1.13a
S-Mila	7.96 ± 1.99b	0.107 ± 0.015bc	1.113 ± 0.017bc	19.15 ± 0.67b

Means marked with the same letters within the same column are not significantly different (Paired-bootstrap, *P* < 0.05).

biological and demographical parameters of *P. xylostella* reared on 10 cultivars of Brassicaceae. These differences may be due to the levels of primary and/or secondary plant compound concentrations as well as to the phenology of plants. These data can be useful to know insect-plant interactions, which in turn help in the design of the best ICM strategy.

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