Bottom-Up Effect of Different Host Plants on *Plutella xylostella* (Lepidoptera: Plutellidae): A Life-Table Study on Canola

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**ABSTRACT** The effects of 10 commercial canola, *Brassica napus* L., cultivars widely grown in Iran—SLM$_{046}$, ‘Opera,’ ‘Okapi,’ ‘RGS$_{903}$,’ ‘Modena,’ ‘Sarigol,’ ‘Zarfam,’ ‘Licord,’ ‘Hayula$_{420}$’ and ‘Talaye’—on the demographic parameters of diamondback moth, *Plutella xylostella* L. (Lepidoptera: Plutellidae), were determined. The experiments were conducted in a growth chamber at 25 ± 1°C, 65 ± 2% RH, and a photoperiod of 16:8 (L:D) h. The comparison of intrinsic rate of natural increase ($r_m$), net reproductive rate ($R_n$), and the survival rate of adult stage of *P. xylostella* on 10 canola cultivars suggested that this pest performed best on SLM$_{046}$. The $r_m$ value of *P. xylostella* ranged between 0.241 on RGS$_{903}$ and 0.304 on SLM$_{046}$. The $R_n$ finite rate of increase ($\lambda$), mean generation time ($T$), and doubling time ($DT$) values of *P. xylostella* on SLM$_{046}$ were 52, 1.35, 13.4, and 2.35 and on RGS$_{903}$ were 31, 1.27, 14.4, and 2.94, respectively. The Weibull model adequately described the shape of the survivorship curve of adult *P. xylostella* from life-table data. A significant fit was obtained with the Weibull model for *P. xylostella* in all experimental canola cultivars. As a result, SLM$_{046}$, Opera, and Hayula$_{420}$ were the most suitable hosts and had least negative impact on life-history statistics of the pest.

**KEY WORDS** *Plutella xylostella*, canola cultivars, life-table analysis, model based survival

The diamondback moth, *Plutella xylostella* (L.) (Lepidoptera, Plutellidae), is recognized as the most pest of cruciferous plants worldwide (Talekar and Shelton 1993, Sarfraz et al. 2006). It also has been reported on other plant families such as Fabaceae (Talekar et al. 1985, Lohr and Rossbach 2004), Chenopodiaceae (Talekar et al. 1993, Sarfraz et al. 2006). It also has been reported on other plant families such as Fabaceae (Talekar et al. 1985, Lohr and Rossbach 2004), Chenopodiaceae (Talekar et al. 1985, Lohr and Rossbach 2004), and Malvaceae (FAO 1971). Crops on which *P. xylostella* larvae feed include cabbage (*Brassica oleracea* variety capitata), cauliflower (*Brassica oleracea* variety botrytis), broccoli (*Brassica oleracea* variety italica), radish (*Raphanus sativus* L.), turnip (*Brassica rapa* pekinensis L.), brussels sprouts (*Brassica oleracea* variety gemmifera), kohlrabi (*Brassica oleracea* variety gongylodes), and more (Kfr 2005).

*P. xylostella* occurs annually throughout the different regions of Iran wherever cruciferous crops are grown and can cause substantial crop losses during outbreak years (Keihanian et al. 2005). In the recent decade, *P. xylostella* has caused major problems on vegetable *Brassica* crops in Iran as elsewhere, mainly due to the increase in levels of resistance to synthetic insecticides. In addition, there has been a dramatic increase in the area of nonvegetable cruciferous plants (e.g., canola, forage brassicas, and cruciferous weeds) growing in Iran that has provided additional resources for *P. xylostella*: see Schellhorn et al. (2008) for a similar story in Australia. In many countries *P. xylostella* has developed resistance to almost every synthetic insecticide used against it, including *Bacillus thuringiensis* formulations (Shelton et al. 1993). In addition to resistance, the destruction of its natural enemies through regular use of broad-spectrum insecticides is considered responsible for its high pest status (Lim 1986; Furlong et al. 2004a,b, 2008).

Even though *P. xylostella* is an important pest of crucifers (Kfr 2005, Sarfraz et al. 2008) life-table studies of this insect on different host plants are not common. In fact, there are few strict demographic studies of *P. xylostella* on its cruciferous host plants, and most of the studies mainly focus on effects of insecticides (Cao and Han 2006), and biological control agents (Furlong et al. 2004a,b, 2008) on the parameters in question. The life-table technique has been used to assess the suitability (or resistance) of host plants to various pest insects (Razmjou et al. 2006). The intrinsic rate of natural increase ($r_m$) is a key demographic parameter that can be used in population growth potential assessment of an animal under a particular environmental condition (Andrewartha and Birch 1954, Ricklefs and Miller 2000, Southwood and Henderson 2000). Value of $r_m$ can be estimated from life-
table data under homogeneous laboratory condition (Southwood and Henderson 2000). Of particular interest to us in this study was the $r_m$, that can be estimated from full life-table studies and used to evaluate the level of plant suitability to herbivory by insects.

Development, survival, reproduction, and subsequent life-table parameters are affected by the host plant type on which the insect is feeding (Ramachandran et al. 1998, Tsai and Wang 2001, Kim and Lee 2002, Liu et al. 2004, Sarfraz et al. 2007). The quality of host plants on which insect larvae feed and develop is the key determinant of the fecundity and fertility of herbivorous insects (Awmack and Leather 2002). The life-table studies on $P. xylostella$ have shown that development and reproduction of $P. xylostella$ can be affected by host plant and geographic area or source of the population (Umeya and Yamada 1973, Sarthooy et al. 1989, Shirai 2000). These differences show that the comparisons between the results of studies undertaken in different regions must be performed with caution.

To describe survival of adult $P. xylostella$, we fitted the Weibull model to our experimental data. The Weibull model is one of the most widely used among survival models found in the literature (Preston et al. 2000). The survival rates evaluated provide a basic estimate under controlled laboratory conditions but cannot be extrapolated to field conditions (Chaves et al. 2004).

The current study aimed to compare the life-table parameters of $P. xylostella$ on different host plant cultivars. The specific objective was to describe the demographic characteristics of $P. xylostella$ under controlled environment conditions and to understand the age dynamics of adult populations of $P. xylostella$ due to variation in 10 commonly grown canola cultivars in Iran and to categorize the resistance status of these cultivars according to the population growth potential of $P. xylostella$. This categorization will enable us to select the most suitable plant cultivar in integrated crop management and to better select hosts for subsequent experiments.

Materials and Methods

Plants and Insects. In March 2009, seeds of canola, *Brassica napus* ‘SLM$_{346}$’, ‘Opera’, ‘Okapi’, ‘RGS$_{003}$’, ‘Modena’, ‘Sarigol’, ‘Zarlam’, ‘Licord’, ‘Hayula$_{420}$’ and ‘Talaye’ (Seed and Plant Improvement Institute, Karaj, Iran) were planted in the research field of Tarbiat Modares University, which is located in the Tehran suburb, 20 km north of the main campus. These cultivars also were grown under greenhouse conditions (27 ± 5°C and a photoperiod of 16:8 [L:D] h) by using field soil without the use of any fertilizer. Four-week-old plants were then transferred to a growth chamber (25 ± 1°C, 65 ± 5% RH, and a photoperiod of 16:8 [L:D] h) to conduct the experiments (below).

$P. xylostella$ were collected from canola fields within Tehran. Separate colonies of $P. xylostella$ were kept on each host plants in ventilated cages (50 by 50 by 60 cm) in above-mentioned greenhouse conditions. At least 120 moths were used to initiate each colony. The moth populations were cultured for more than two generations on each host plant before performing the experiments (below).

Life-Table Parameters Estimation. To obtain the synchronized eggs of $P. xylostella$, leaves of host plants were placed for 20 h in ventilated Plexiglas oviposition cages (30 by 30 by 30 cm) containing 20 pairs of newly emerged $P. xylostella$ (male and female) reared from the same host plant. The adults were fed with aqueous honey solution (10%). The eggs laid on the leaves were then used for the experiments. A cohort life table was constructed based on unlimited food supply, where natural enemies were excluded from the experiment.

To measure reproduction, pairs of newly emerged $P. xylostella$ (male and female) reared on each host plant were placed in ventilated Plexiglas cylindrical cages (20 cm in diameter and 15 cm in height) containing the same host plant leaves. For each cage, replacement leaves were provided ad libitum from the same type as the original plants, until all the females had died. The number of eggs laid were recorded daily, and the data used as a measure of fecundity. Each treatment (cultivar) was replicated 20 times (moth pairs).

The intrinsic rate of natural increase ($r_m$), mean generation time ($T$), finite rate of increase ($\lambda$), doubling time ($DT$), and net reproduction rate ($R_0$) were determined using formulae from Carey (2001).

Model-Based Survival Profile. Life-table data of $P. xylostella$ were explored for patterns in survival. The Weibull (equation 1 model was used to describe the shape of survivorship curve with adult age $t$ (in days). This survival model (Carey 2001) uses the Weibull distribution (Gurney and Nisbet 1998). Here $b$ is the scale and $c$ the shape parameters (Carey 2001). Values of $c$ parameter correspond to survival curve type I ($c > 1$), II ($c = 1$), or III ($c < 1$), respectively.

$$S_t = e^{-b/c^t}, \quad (t > 0) \tag{1}$$

Model evaluation was made based upon goodness-of-fit. Statistical values of $R^2$ and residual sum of squares (RSS) of the model on different cultivars of canola used to discriminate model fitness among cultivars.

Cluster Analysis. A dendrogram of canola cultivars based on some life-table and reproduction parameters of $P. xylostella$ reared on different cultivars of canola was constructed after cluster analysis by Ward’s Minimum Variance method using SAS statistical software (Proc Cluster, SAS Institute 2003). Parameters used in cluster analysis include $R_m$, $r_m$, $\lambda$, gross reproductive rate (GRR), gross fecundity rate, gross fertility rate, net fecundity rate, net fertility rate, total fecundity, and birth rate ($b$). Data of the last seven parameters were not shown here.

Statistical Analysis. Data obtained from the experiments were analyzed using analysis of variance (ANOVA) (Proc GLM, SAS Institute 2003). Jackknife estimates of the life-table parameters and data obtained from fecundity measurements were analyzed per cultivar with unbalanced one-way ANOVA (Proc
Table 1. Life-table parameters of P. xylostella obtained using jackknife simulation method, on 10 canola cultivars

<table>
<thead>
<tr>
<th>Canola cultivar</th>
<th>R₀</th>
<th>rₘ</th>
<th>T</th>
<th>DT</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLM₄₄₆</td>
<td>51.5 ± 4.29ab</td>
<td>0.304 ± 0.01a</td>
<td>13.4 ± 0.07d</td>
<td>2.35 ± 0.05g</td>
<td>1.35 ± 0.009a</td>
</tr>
<tr>
<td>Okapi</td>
<td>46.1 ± 2.62bc</td>
<td>0.286 ± 0.00ab</td>
<td>13.2 ± 0.07d</td>
<td>2.40 ± 0.04fg</td>
<td>1.33 ± 0.006ab</td>
</tr>
<tr>
<td>Modena</td>
<td>35.1 ± 1.90de</td>
<td>0.259 ± 0.00cd</td>
<td>13.6 ± 0.13cd</td>
<td>2.63 ± 0.059de</td>
<td>1.30 ± 0.007cd</td>
</tr>
<tr>
<td>RGS₉₀₃</td>
<td>30.6 ± 1.48e</td>
<td>0.241 ± 0.00ed</td>
<td>14.4 ± 0.13ab</td>
<td>2.94 ± 0.04a</td>
<td>1.27 ± 0.006e</td>
</tr>
<tr>
<td>Talaye</td>
<td>38 ± 1.35bcde</td>
<td>0.270 ± 0.00be</td>
<td>13.3 ± 0.10bd</td>
<td>2.54 ± 0.04def</td>
<td>1.30 ± 0.007cd</td>
</tr>
<tr>
<td>Zarfam</td>
<td>57.3 ± 3.92d</td>
<td>0.278 ± 0.00bd</td>
<td>14.6 ± 0.13a</td>
<td>2.32 ± 0.056eg</td>
<td>1.32 ± 0.008he</td>
</tr>
<tr>
<td>Opera</td>
<td>41.7 ± 4.29ed</td>
<td>0.258 ± 0.00cd</td>
<td>14.5 ± 0.17a</td>
<td>2.83 ± 0.10ab</td>
<td>1.29 ± 0.013de</td>
</tr>
<tr>
<td>Sarigol</td>
<td>38.2 ± 2.68cde</td>
<td>0.253 ± 0.00cd</td>
<td>14 ± 0.18bc</td>
<td>2.73 ± 0.06bc</td>
<td>1.29 ± 0.005de</td>
</tr>
<tr>
<td>Licord</td>
<td>36.8 ± 2.23cde</td>
<td>0.255 ± 0.00cd</td>
<td>13.6 ± 0.17cd</td>
<td>2.71 ± 0.06bcd</td>
<td>1.29 ± 0.007cd</td>
</tr>
<tr>
<td>Hayula₆₂₀</td>
<td>55.2 ± 4.21a</td>
<td>0.287 ± 0.00ab</td>
<td>13.8 ± 0.22c</td>
<td>2.44 ± 0.08fg</td>
<td>1.31 ± 0.012ab</td>
</tr>
</tbody>
</table>

Values are means ± SE. Means in each column followed by the same letter are not significantly different at the P = 0.05 level (Duncan’s multiple range test after one-way ANOVA).

GLM, SAS Institute (2003) and means were compared by Duncan’s multiple range test, accepting significant differences at P < 0.05. R² and RSS values of the Weibull model used to describe survival of adults emerging from different canola cultivars and descriptive statistics of all demographic parameters were obtained using MINITAB release 15 statistical software (Minitab 2007). Initial estimates of the Weibull model’s parameters were obtained with statistical package JMP version 7.0 (SAS Institute 2007).

Results

Life-Table Parameters. Among the various cultivars, the R₀ values of adult P. xylostella showed significant differences (F = 9.36; df = 9, 150; P < 0.0001). The cohorts reared on Zarfam, SLM₄₄₆ and Hayula₆₂₀ had the largest R₀ values, and those on RGS₉₀₃, Modena, Licord, Talaye, and Sarigol had the smallest R₀ values (Table 1). In addition, the T values of P. xylostella on RGS₉₀₃, Opera, and Zarfam (relatively unsuitable cultivars) were significantly higher (F = 13.01; df = 9, 154; P < 0.0001) than on the relatively susceptible cultivars, namely, SLM₄₄₆, Talaye, Okapi, Modena, and Licord (Table 1). Furthermore, the DT values of P. xylostella showed significant differences (F = 10.51; df = 9, 154; P < 0.0001), being higher on RGS₉₀₃ and Opera than on other cultivars. In addition, the finite rate of increase (λ) of P. xylostella was significantly lower (F = 8.38; df = 9, 164; P < 0.0001) on RGS₉₀₃, Opera and Sarigol than on others (Table 1). The rₘ values were found to be significantly different (F = 10.24; df = 9, 148; P < 0.0001) depending on the canola cultivar on which they were reared. The rₘ value was higher on SLM₄₄₆ followed by Hayula₆₂₀ and Okapi (Table 1). The rₘ value of P. xylostella calculated on ten cultivars examined ranged from 0.241 on RGS₉₀₃ to 0.304 on SLM₄₄₆ / T / D (Table 1).

Survivorship, Longevity, and Fecundity. The age-specific survival rate (lₓ) at age of adult emergence of P. xylostella on SLM₄₄₆, Okapi, Modena, RGS₉₀₃, Talaye, Zarfam, Opera, Sarigol, Licord, and Hayula₆₂₀ were 0.79, 0.71, 0.65, 0.67, 0.69, 0.74, 0.52, 0.64, 0.62, and 0.56, respectively. The lₓ curves of the pest for ten different cultivars (Fig. 1) in general showed a similar pattern with high mortality occurring during first and last 5 d. Mortality was high particularly in the incubation period and first-instar larvae with numbers then declining slowly until the adult stage with high mortality again during the last 5 d of the life span (Fig. 1). The male and female longevity of adult P. xylostella (mean number of days from eclosion to death) was significantly different (F = 13.83; df = 9, 155; P < 0.0001) depending on the cultivar examined (Table 1). The number of offspring per female per day were generally found to have the highest fecundity, whereas the least fecundity was on RGS₉₀₃ and Okapi for males and females, respectively (Table 2).

Significant effects were observed for total fecundity of P. xylostella females (F = 3.89; df = 9, 176; P < 0.0002). Means for the total number of offspring per female ranged from 184.2 on Hayula₆₂₀, to 99.63 on RGS₉₀₃ (Table 2). The number of offspring per female per day were significantly different among cultivars (F = 2.71; df = 9, 176; P < 0.005). Values ranged between 53.1 for Modena to 27.66 for Hayula₆₂₀ (Table 2). The mₙ schedule of P. xylostella on various cultivars of canola is shown in Fig. 1. The oviposition period of females was initiated on days 16, 16, 16, 17, 17, 17, 17, and 15 on SLM₄₄₆, Okapi, Modena, RGS₉₀₃, Talaye, Zarfam, Opera, Sarigol, Licord, and Hayula₆₂₀, respectively. The peak of female oviposition was at oviposition initiation days on eight cultivars, but this peak was on days 18 and 19 on Zarfam and Sarigol, respectively (Fig. 1). The life expectancy of 1-d-old eggs on the first day was estimated to be 17.4, 15.6, 16, 17, 16, 18.7, 16, 14.5, 14.6, and 16.9 d on SLM₄₄₆, Okapi, Modena, RGS₉₀₃, Talaye, Zarfam, Opera, Sarigol, Licord, and Hayula₆₂₀, respectively. Consequently, the life expectancy of P. xylostella was better on SLM₄₄₆, Opera, and Hayula₆₂₀. In other words, these cultivars were the most suitable hosts and had least negative impact on life-history statistics of the pest.

Model-Based Survival Profile. A significant fit was obtained with the Weibull model for adult P. xylostella survival on all experimental canola cultivars. The scale parameter (b) was higher in Hayula₆₂₀ than on other cultivars, revealing a significant survival differential. The parameter values ranged between 8.06 for Okapi (R² = 0.99, RSS = 0.012) and 16.88 for Hayula₆₂₀ (R² = 0.95, RSS = 0.084) for all cultivars, the shape parameter (c) of the Weibull
model corresponded to type I survival curve \( (c > 1); \) Fig. 2).

Clustering. A dendrogram of plant cultivars based on the demographic parameters of \( P. xylostella \) reared on different canola cultivars is shown in Fig. 3. Cutting the dendrogram at the \(<0.2\) distance (semipartial \( R^2 \)) showed two distinct clusters labeled A, and B. Ten cultivars of canola were grouped within each cluster based on the comparison of the selected parameters of the life history and fecundity of \( P. xylostella \) reared on respective cultivars. The cluster A included three cultivars—SLM\(_{46}\), Opera, and Hayula\(_{420}\) (best hosts with high potential of population growth)—and the cluster B consisted of Okapi, Licord, Zarfam, Sarigol, Modena, RGS\(_{903}\), and Talaye, which can be categorized as most inferior hosts of those tested.

![Fig. 1. Survival rate (\( l_x \)) and fecundity (\( m_x \)) of \( P. xylostella \) on ten canola cultivars at 25°C.](image-url)
**Discussion**

Life history of *P. xylostella* varies noticeably depending upon host plant and environmental conditions (Ooi 1986, Shelton et al. 1991, Muhamed et al. 1994, Liu et al. 2002). Our study evaluated the effects of host plant on performance of *P. xylostella* under fixed laboratory conditions in Iran. The results revealed the obvious effects of host plant cultivar on the survival and life-table parameters of *P. xylostella*. Our study showed that *P. xylostella* fed, survived, and developed on 10 commonly grown canola cultivars in Iran and that host plant type could greatly affect its $r_m$, $R_p$, female progeny, and the survival of the adult stage. These findings are in agreement with the previous studies, which demonstrated that the host plant significantly affects the development and reproduction of *P. xylostella* (Dube and Chand 1977, Ramachandran et al. 1998, Shelton 2001, Golizadeh et al. 2009). Effects of host plant on the demographic parameters of this pest have been studied on canola (Ebrahimi et al. 2008, Golizadeh et al. 2009), cabbage and cauliflower (Golizadeh et al. 2008), *Brassica* sp. (Sarfraz et al. 2007, 2008), and *Brassica napus* L. and *Brassica rapa* L. (Karinzadeh et al. 2004). Among these studies, there is considerable variation in life-table parameters, especially the intrinsic rate of natural increase. Differences in nutritional content among host plants most likely cause differences between the results of different studies. Moreover, variation could be due to differences among geographic populations of *P. xylostella* (Umeya and Yamada 1973, Sarntthoy et al. 1989, Shirai 2000). Plant quality varies significantly depending upon external environmental factors, too, and these could be cited as other reasons for the resulting differences (Awmack and Leather 2002).

There was a significant difference observed in $r_m$ with respect to host plants in our study. Our $r_m$ values, by contrast, were higher than those recorded previously (Syed and Abro 2003), 0.160 on canola, whereas the value in Golizadeh et al. (2009), 0.244, on canola ‘PF’ was close to those estimated in the current study. Wakisaka et al. (1992) estimated the $r_m$ value of *P. xylostella* on different host plants and found that $r_m$ ranged between 0.2778 and 0.1362 on broccoli and a wild crucifer plant, respectively. Salas et al. (1993) studied the life-table parameters of *P. xylostella* on different host plants and found that the highest $r_m$ occurred when the insect fed on cauliflower ($r_m = 0.239$). The different results of various studies could be attributed to cultivar differences as well as to strains of *P. xylostella*. In the current study, the $R_p$ value on RGS001 was much lower than values obtained on the other host plants. This difference was probably a result of different food sources taken up by the adults during larval stage. The survival rate on Hayula420 was lowest compared with that on the other hosts. This difference could be due to the presence of nutritional, and phagostimulant factors (such as carbon and nitrogen) as well as defensive metabolites that directly affect potential and achieved herbivore development and fecundity (Awmack and Leather 2002, Syed and Abro 2003.

### Table 2

<table>
<thead>
<tr>
<th>Canola cultivar</th>
<th>Preoviposition period (d)</th>
<th>Oviposition period (d)</th>
<th>Postoviposition period (d)</th>
<th>Total oviposition period (d)</th>
<th>Daily fecundity</th>
<th>Female longevity</th>
<th>Fecundity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Olapi</td>
<td>0.17 ± 0.11 (n = 20)</td>
<td>2.35 ± 0.23 (n = 20)</td>
<td>4.20 ± 0.35 (n = 19)</td>
<td>7.80 ± 0.55 (n = 19)</td>
<td>0.36 ± 0.18</td>
<td>14.0 ± 0.9</td>
<td>5.7 ± 0.8</td>
</tr>
<tr>
<td>Modena</td>
<td>0.13 ± 0.11 (n = 18)</td>
<td>2.53 ± 0.23 (n = 18)</td>
<td>4.25 ± 0.35 (n = 17)</td>
<td>7.80 ± 0.55 (n = 17)</td>
<td>0.32 ± 0.17</td>
<td>14.0 ± 0.9</td>
<td>5.3 ± 0.8</td>
</tr>
<tr>
<td>RGS003</td>
<td>0.19 ± 0.11 (n = 20)</td>
<td>2.75 ± 0.23 (n = 20)</td>
<td>4.35 ± 0.35 (n = 19)</td>
<td>7.95 ± 0.55 (n = 19)</td>
<td>0.35 ± 0.19</td>
<td>14.0 ± 0.9</td>
<td>5.7 ± 0.8</td>
</tr>
<tr>
<td>Zarfam</td>
<td>0.17 ± 0.11 (n = 18)</td>
<td>2.45 ± 0.23 (n = 18)</td>
<td>4.10 ± 0.35 (n = 17)</td>
<td>7.85 ± 0.55 (n = 17)</td>
<td>0.34 ± 0.18</td>
<td>14.0 ± 0.9</td>
<td>5.4 ± 0.8</td>
</tr>
<tr>
<td>SLM046</td>
<td>0.17 ± 0.11 (n = 18)</td>
<td>2.40 ± 0.23 (n = 18)</td>
<td>4.05 ± 0.35 (n = 17)</td>
<td>7.80 ± 0.55 (n = 17)</td>
<td>0.33 ± 0.17</td>
<td>14.0 ± 0.9</td>
<td>5.3 ± 0.8</td>
</tr>
<tr>
<td>Hayula420</td>
<td>0.25 ± 0.11 (n = 17)</td>
<td>2.20 ± 0.23 (n = 17)</td>
<td>4.10 ± 0.35 (n = 17)</td>
<td>7.95 ± 0.55 (n = 17)</td>
<td>0.29 ± 0.17</td>
<td>14.0 ± 0.9</td>
<td>5.3 ± 0.8</td>
</tr>
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</table>

Values are means ± SE. Means in each column followed by the same letter are not significantly different at the P = 0.05 level (Duncan’s multiple range test after one-way ANOVA).
In our study, \( T \) on Opera, RGS003, and Zarfam were longer than on SLM046, Okapi, and Talaye. The high value of \( R_0 \) on SLM046, Zarfam, and Hayula420 is reflected in high \( r_m \) values.

Many factors, such as fecundity, survival, and specifically generation time, affect \( r_m \), and this parameter adequately summarizes the physiological qualities of an insect in relation to its capacity to...

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**Fig. 2.** Fitting Weibull survival model to observed values of age-specific survival \( (l_x) \) of \( P. xylostella \) on ten canola cultivars. Dotted lines and solid lines represent model estimated and observed data, respectively.
increase, so it would be a most appropriate index to evaluate the performance of an insect on different host plants and the host plant’s resistance (Kocourek et al. 1994, Southwood and Henderson 2000). The high \( r_m \) values on SLM046 and Hayula420 indicated that \( P. \) xylostella has a greater reproductive potential and there are presumably more suitable hosts than the other plants evaluated. RGS003 had the highest antibiosis resistance against \( P. \) xylostella and was the least favorable of the hosts evaluated for this pest as indicated by the long developmental time and low survival rate of immature stages (Soufbaf et al. 2010), as reflected in a lower value of \( r_m \). Such antibiosis effects could cause reduction in survival fitness of \( P. \) xylostella; for example, prolonged developmental time could increase the exposure of the insect to its natural enemies. The high net reproductive rate and the short doubling time of \( P. \) xylostella on SLM046 may cause the relatively high densities of \( P. \) xylostella, which might be expected on cruciferous plants in the field.

Presumably reduced fecundity arising from larval feeding on nutritionally poor plants can rebound to low number of eggs laid on a plant (Verkerk and Wright 1996, Hamilton et al. 2005). This differential suitability of host plant cultivars to \( P. \) xylostella can be an essential factor to consider while exploring integrated pest management (IPM) programs for this pest. For example, intercropping, rotation, or a combination of SLM046 and RGS003 could be used to reduce the abundance of the pest within a \( Brassica \) farm. Relative resistance of different genotypes of \( Brassica \) to each insect species was independent of the level of resistance to other insects feeding on \( Brassica \) (Radcliffe and Chapman 1966, Shelton et al. 1988). Therefore, the unsuitability of some cultivars for \( P. \) xylostella shown in the current study could be valuable in field situations where there is a pest complex.

Cluster analysis indicated that with respect to the comparative demography and fecundity of \( P. \) xylostella, grouping the different cultivars of canola within each cluster might be due to a high correspondence of physiological traits of canola cultivars, whereas the separate clusters might represent significant variability in host plant suitability between clusters. The results of the comparison of demographic parameters of \( P. \) xylostella on different cultivars of canola revealed that the cluster A included the best hosts (SLM046, Opera, and Hayula420) and the cluster B included the least suitable host plant cultivars (Okapi, RGS003, Modena, Sarigol, Zarfan, Licord, and Talaye) for the population growth of \( P. \) xylostella. In conclusion, cluster A included the most pest-susceptible host plants with higher intrinsic rate of natural increase, and finite rate of increase, and lower birth rate of \( P. \) xylostella reared on cultivars grouped in this cluster. However, cluster B cultivars had lower fecundity, higher mortality, and a longer developmental time on the related canola cultivars.

A fundamental element of an IPM program for any crop is an understanding of the extent resistance in different cultivars, population growth potential of a pest, and the biology of a pest on a crop that can inform the detection and monitoring of pest infestations, cultivar selection, and crop breeding (Razmjou et al. 2006). It has been shown that an insect diet will affect its survival and reproduction and that plant-feeding insects are dependent on the quantity and quality of nutrients in their host plant. The use of resistant and partially resistant (Karimzadeh et al. 2006) cultivars can enhance biological and chemical control methods as part of an IPM strategy (van Steenis and El-Khawass 1995, Du et al. 2004). Consequently, it is considerable that our findings may provide important information for designing a comprehensive program for IPM of \( P. \) xylostella in Iran.
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