Bottom-up and top-down effects in a tritrophic system: the population fluctuations of Plutella xylostella and its parasitoid, Oomyzus sokolowskii on the cauliflower cultivars in field conditions

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Bottom-up and top-down effects in a tritrophic system: the population fluctuations of *Plutella xylostella* and its parasitoid, *Oomyzus sokolowskii* on the cauliflower cultivars in field conditions

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The diamondback moth, *Plutella xylostella* (L.) (Lepidoptera: Yponomeutidae), has worldwide distribution and found wherever cruciferous plants is grown. In this study, fluctuations of parasitism rate of *P. xylostella* by *Oomyzus sokolowskii* on different cauliflower cultivars were evaluated in the field during 2011 at research station of the Shahed University (South of Tehran). This investigation was conducted on the eight cauliflower cultivars including Smilla, Snow mystique, White cloud, Buris, Galiblanka, Snow crown, SG and Tokita in a randomised complete block design with five replications. The results showed that density of total larva and pupa of the diamondback moth on Buris and Snow crown cultivars is lower than other cultivars. The highest and the lowest percentage of parasitism by *O. sokolowskii* was observed on Buris cultivar (7.93 ± 0.91%) and SG cultivar (1.28 ± 0.36%) during the season, respectively.

**Keywords:** *Plutella xylostella; Oomyzus sokolowskii; cauliflower cultivars; tritrophic system*

**Introduction**

The diamondback moth, *Plutella xylostella* (L.) (Lep.: Plutellidae) is one of the most important pests of cruciferous plants. So that control operations against this pest are performed every 5–10 days in some cauliflower fields in Iran (Hasanshahi 2012). There are many reports about resistance of the diamondback moth to ordinary insecticides in Iran (Mahmoudvand et al. 2011a, 2011b) and other parts of the world (Sun et al. 1995; Feng et al. 2004; Zhao et al. 2006). It seems that, other management programmes are essential to control this pest. These are including management programme for pest control is the use of resistant cultivars. The use of resistant cultivars is one of the effective methods for controlling pests in different crops. The use of resistant cultivars has many advantages in integrated pest management. Resistant cultivars reduce pest damage with the least cost for farmers (Reagan et al. 1997). Resistant cultivars due to resistance mechanism type could affect pest population in a short time or long term, despite the existence of pest, yield reduction is not found in the product (Nouri Ghanblani et al. 1995). Cruciferous plants have different susceptibility to the diamondback moth.

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The presence of wax in leaf surface can be one of the reasons. Kohlrabi and turnip are among resistant Cruciferous plants to this pest (Eigenbrode & Trumble 1994; Eigenbrode et al. 1995; Capinera 2001). Presence of wax in smooth and shiny leaves is caused rejection of plants by neonate larvae. Larva in this type of plant tissue expend more time for searching and less time to feeding. This cultivars improved mobility of some of the predators that power of well move, have not in ordinary crucifer crops (Eigenbrode & Trumble 1994; Eigenbrode et al. 1995). Other effective factors in population decline and damage of the DBM are parasitoids. More than 150 species of parasitoid wasps are active on P. xylostella (Hasanshahi 2012). Oomyzus sokolowskii is one of the most abundant parasitoids of the DBM in many areas (Kfir 1997; Liu et al. 2002). This parasitoid is primary and gregarious parasitoids of larvae – pupae of the diamondback moth. Of course, these parasitoids sometimes are active as hyperparasitoid and it uses Cotesia plutellae pupae and other parasitoids (Fitton & Walker 1992; Liu et al. 2002). This species is adapted to high temperature conditions (Talekar & Hu 1996). This parasitoid is more active in Virginia at the end of season and is more active in regions with high temperatures (Cordero 2005). Chemical symptoms produced by plants can be affected on organism’s second level of nutrition (herbivores), also organism’s third level (parasitoids and predators) (Dent 2000). This effect may be positive and is caused to attract natural enemies to the plant, which in this case is caused to reduce the population of herbivorous insects on the plant. This chemical relationship is in favour of natural enemies and plant (Barbosa 1988). In some specific conditions, may increase severely evaporation of chemical materials of plant and this increase will be followed by a normal reaction. In some cases, increase in chemical materials concentration is due to physical damage of plant branch and leaf. It is shown that injury and physical damage in various parts of plant, especially the leaves will increase release amount of odorous chemical materials due to their oxidation. It is possible that attraction of natural enemies to plant is also increased (Van Edeman 1990). Use of resistant cultivars will affect on pest parasitoids in addition to reducing the pest population. Use of resistant cultivars that may lead to reduce pest populations and increase the efficiency of parasitoids. Due to importance of constituencies, present study was conducted for the first time on different cauliflower cultivars and provides a management programme solution.

Materials and methods
Population fluctuation of the diamondback moth, P. xylostella was tested during 2011 under natural infestation at research station of the Shahed University (South of Tehran, Iran). This investigation was conducted on the eight cauliflower cultivars including Smilla, Snow mystique, White cloud, Buris, Galiblanka, Snow crown, SG and Tokita. Cauliflower cultivars were planted in the field in randomised complete-block design with five replications in 40 plots from mid June. Sampling was carried out at farm an area of 600 square metres. Sampling of different developmental stages (larvae and pupae) was regularly carried out every 10 days. Sampling was done with direct observation and counting the different developmental stages of the pest. Three plants were evaluated per each experimental plot. Three leaves of each plant were randomly selected (totally 15 leaves for each cultivar). The diamondback moth begins their damage in transplanting stage and will continue until flowering stage and harvest. Collected larvae and pupae on each plant with cut pieces of host plant were transported to the growth chamber at 25 ± 2 °C and 65 ± 5% RH and 16L:8D photoperiod. Larvae related
to each plant and each cultivar was placed in clear plastic containers (5 × 20 × 10 cm) that was contained the leaf of each cultivar, separately. For survival of leaves, end of leaves was placed in wet cotton. The leaves were replaced once every two or three days with fresh ones. Diamondback moth pupa was placed inside the glass tubes (1 × 10 cm) and was kept until appearance of adults or parasitoids. Samples were evaluated on a daily basis and parasitoids were kept in 75% alcohol.

Statistical analyses
Analyses of variance for a completely randomised block design were performed to test the differences between treatments, and means were compared at the 5% level of significance using Duncan studentized range test (Littell et al. 2002; SAS Institute 2004). For analysis and mean comparison, mean of different developmental stages in each sampling date was considered as a replicate.

Results

Population fluctuation of total larva and pupa stages of the DBM on different cauliflower cultivars

Population fluctuations of total larva and pupa of *P. xylostella* on different cultivars are shown in Figure 1. As it is shown, Snow mystique cultivar had the highest number of

![Figure 1. Population fluctuations of total larva and pupa stages of the *P. xylostella* on different cauliflower cultivars.](image)
total larva and pupa in compare with other cultivars in the beginning of season. Buris and Snow crown cultivars had the lowest number of total larva and pupa among cultivars in the beginning of season. The lowest number of total larvae and pupa was observed on Buris cultivar and the highest number of total larva and pupa was seen on Tokita cultivar at the end of season. The highest density of total larva and pupa was observed during the season and on total cultivars at the end of season. In this time, Snow mystique cultivar had the highest number of total larva and pupa and Buris had the lowest number of larva and pupa per leaf. Population fluctuations of total larva and pupa on Buris and Snow crown cultivars are lower than other cultivars during the season.

**Fluctuations of parasitism of DBM by O. sokolowskii on different cauliflower cultivars**

Fluctuations of percentage of parasitism by *O. sokolowskii* on different cauliflower cultivars are shown in Figure 2. Percentage of parasitism was highest on Smilla and Tokita cultivars in the beginning of season. At the same time, there was not observed parasitoid on Galiblanka and Snow crown cultivars. This trend continued on Snow crown cultivar to 10 September and on Galiblanka cultivar to 20 August. The highest parasitism was observed on White cloud and Snow crown cultivars and the lowest was occurred on Galiblanka and SG cultivars at the end of season. In all sampling times, the highest and lowest rate of parasitism was recorded on Buris (7.93 ± 0.91%) and SG cultivars (1.28 ± 0.36%). In addition, the highest percentage of parasitism in all cultivars was occurred in 21 October. The highest parasitism rate was observed on Buris cultivar (10.00 ± 5.66%) and the lowest one was observed on Galiblanka (1.66 ± 1.66%).

![Figure 2. Population fluctuations of parasitism of the DBM by *O. sokolowskii* on different cauliflower cultivars.](image-url)
**Relationship between pest density and parasitism of O. sokolowskii on different cauliflower cultivars**

Relationship between pest density and percentage of parasitism of *O. sokolowskii* on different cauliflower cultivars during the season is shown in Figure 3. Due to difference between percentage of parasitism (8.06 ± 1.51) and pest density (3.37 ± 0.15), Buris cultivar was the most suitable cultivar for parasitoid activity on the diamondback moth. The highest pest density and the lowest percentage of parasitism were on Smilla and Snow mystique cultivars. It seems that these two cultivars were not suitable for parasitoid activity.

**Comparison of pest density, parasitism rate and number of parasitoids appearance on different cauliflower cultivars**

The statistical comparison of measured traits on different cauliflower cultivars is shown in Table 1. There is significant difference between density of DBM on different cultivars (Table 2). The highest and the lowest pest density were observed on Smilla and Snow crown cultivars, respectively. The highest percentage of parasitism by *O. sokolowskii* was observed on Buris cultivar and the lowest was on SG and Galibanka cultivars. Number of parasitoids appearance from pest pupa was the highest on Tokita and

![Figure 3. Relationship between pest density and parasitism of O. sokolowskii on different cauliflower cultivars.](image)

**Table 1. Comparison of measured traits on different cauliflower cultivars.**

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>Density of DBM (pest density)</th>
<th>Parasitism rate (%)</th>
<th>Number of parasitoids appearance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smilla</td>
<td>0.23 ± 0.02a</td>
<td>6.11 ± 0.61b</td>
<td>8.48 ± 0.35a</td>
</tr>
<tr>
<td>Snow mystique</td>
<td>0.26 ± 0.02a</td>
<td>2.91 ± 0.17c</td>
<td>8.07 ± 0.44a</td>
</tr>
<tr>
<td>White cloud</td>
<td>0.15 ± 0.01b</td>
<td>6.39 ± 0.39ab</td>
<td>3.34 ± 0.30b</td>
</tr>
<tr>
<td>Buris</td>
<td>0.09 ± 0.01b</td>
<td>7.92 ± 0.91a</td>
<td>3.41 ± 0.29b</td>
</tr>
<tr>
<td>Galibanka</td>
<td>0.15 ± 0.02b</td>
<td>1.28 ± 0.37c</td>
<td>4.00 ± 0.30b</td>
</tr>
<tr>
<td>Snow crown</td>
<td>0.08 ± 0.01b</td>
<td>1.57 ± 0.65c</td>
<td>3.75 ± 0.25b</td>
</tr>
<tr>
<td>SG</td>
<td>0.15 ± 0.02b</td>
<td>1.28 ± 0.36c</td>
<td>5.14 ± 0.59a</td>
</tr>
<tr>
<td>Tokita</td>
<td>0.26 ± 0.03a</td>
<td>5.14 ± 0.57b</td>
<td>8.62 ± 0.48a</td>
</tr>
</tbody>
</table>
As shown in Table, pest density was not effective on percentage of parasitism. Because, there is no significant difference between pest density on Buris and White cloud cultivars with Galiblanka, Snow crown and SG cultivars. But there is significant difference between percentage of parasitism on Buris and White cloud cultivars with Galiblanka, Snow crown and SG cultivars.

**Regression between density of DBM and parasitism rate on different cultivars**

According to Table 3, there are significant differences in regression between DBM density and parasitism rate of *O. sokolowski* in Smilla and Tokita Cultivars (*p* < 0.05). Given that correlation coefficient has lower value in all cultivars. It cannot be concluded that parasitism by this parasitoid has increase with density increases of the DBM larvae. Maybe there are other factors impressible on parasitism rate of *O. sokolowski*.

**Discussion**

In this study, three species of parasitoids were identified on *P. xylostella* that each of them has different activities on different cauliflower cultivars. These species of parasitoids were including *Diadegma anurum*, *Cotesia plutellae* and *O. sokolowskii*. Hasanshahi (2012) reported that activity rate of these three parasitoids in Tehran is between 10 and 40% on cauliflower. In our study, population fluctuations of total larva

### Table 2. Analysis of variance of measured traits on different cauliflower cultivars.

<table>
<thead>
<tr>
<th>Traits</th>
<th>Resources changes</th>
<th>df</th>
<th>Mean square</th>
<th>F</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pest density</td>
<td>Different cultivars</td>
<td>7</td>
<td>0.05</td>
<td>8.98</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Error</td>
<td>80</td>
<td>0.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>87</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parasitism rate</td>
<td>Different cultivars</td>
<td>7</td>
<td>62.58</td>
<td>22.72</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Error</td>
<td>80</td>
<td>2.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>87</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of parasitoids appearance</td>
<td>Different cultivars</td>
<td>7</td>
<td>1444.75</td>
<td>32.72</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Error</td>
<td>80</td>
<td>4.42</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>87</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Regression coefficients ($R^2$) between DBM density and parasitism rate of *O. sokolowskii* on different cultivars ($R^2$ ($F$)).

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>$R^2$ ($F$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smilla</td>
<td>0.69 (15.98)**</td>
</tr>
<tr>
<td>Snow mystique</td>
<td>0.27 (2.70)**</td>
</tr>
<tr>
<td>White cloud</td>
<td>0.06 (0.50)**</td>
</tr>
<tr>
<td>Buris</td>
<td>0.01 (0.04)**</td>
</tr>
<tr>
<td>Galiblanka</td>
<td>0.02 (0.20)**</td>
</tr>
<tr>
<td>Snow crown</td>
<td>0.032 (3.80)**</td>
</tr>
<tr>
<td>SG</td>
<td>0.17 (1.49)**</td>
</tr>
<tr>
<td>Tokita</td>
<td>0.62 (11.52)*</td>
</tr>
</tbody>
</table>

**Significant at 1% probability level.

*Significant at 5% probability level.

*Non significant.
and pupa on Buris and Snow crown cultivars is lower than other cultivars, this shows that number of larva and pupa is lowest in this cultivar than others during the season. Therefore, resistance in these two cultivars than density of larvae of DBM can be reported. Fathi et al. (2010) studied population density of *P. xylostella* on canola cultivars in Ardabil region of Iran. Population changes of the DBM evaluated in Karaj in 2007–2008 and the highest density of pest was calculated 37.9 insect and the highest density of larva per plant was calculated 35.83 insect (Golizadeh 2008). In present study, different cultivars show changes with plant phenology. So that different cultivars have more susceptibility than density of DBM in early developmental stage. Other researchers showed that different cultivars resistance is differed in various stages of plant growth and use of resistant cultivars can be affected on growth parameters of pest (Esmaeili-Vardanjani et al. 2013, Jahan et al. 2013a). In present study, the highest and the lowest percentage of parasitism was observed on Buris (7.93±0.91%) and SG cultivars (1.28±0.36%), respectively. It seems that SG cultivar was not suitable for parasitoid activity. Different plant cultivars or plant species can be affected through physical and biochemical characteristics or indirectly through host dietary on behaviour and performance characteristics of natural enemies (Price 1986). Field study on plant species of *Brassica* in New Zealand showed that percentage of parasitism by *Diadromus collaris* and *Diadegma semiclausum* on species of *B. oleracea* var. *botrytis* is more than other cultivars (Beck & Cameron 1990). *D. insulare* parasitism rate on the DBM larvae on *Sinapis arvensis* plant was more than *B. napus* (Idris & Graffius 1995). Based on the results of Table 1, there is relationship between pest density and number of parasitoids appearance. So that pest density was highest on Buris, Snow mystique and Tokita cultivars and on the other hand, number of parasitoids appearance was highest in these cultivars. The lowest pest density was on Buris, White cloud, Galiblanka and Snow crown cultivars. So that pest density of these cultivars had significant differences with other cultivars. Also in these cultivars, number of parasitoids appearance was lowest then other cultivars. Parasitism of larvae by *Cotesia plutellae* reared on plants of *Brassica campestris* was more than larvae reared on *Brassica oleracea* L. var. *capitata* (Liu & Jiang 2003). The results related of pest density in our study showed that by increasing pest density, number of parasitoids appearance was also increased. Talekar and Yang (1991) were evaluated parasitism of *Diadegma semiclausum* and *Cotesia plutellae* on four species of *Brassica*. Hasanshahi, Abbasipour, Askarianzadeh, et al. (2013) were studied density of different developmental stages the DBM moth on eight cauliflower cultivar and was observed the lowest contamination level of this pest on Buris, Snow crown cultivars. It seems that these two cultivars have more resistance than other cultivars. Also in our study, these two cultivars are considered as resistant cultivars. Askarianzadeh et al. (2013) were evaluated quantitative damage of *P. xylostella* on different canola cultivars. Results of this study showed that among the studied cultivars, Hyola420 and Hyola308 cultivars have more resistance to density of the diamondback moth. Hasanshahi, Abbasipour, Jahan, et al. (2013) were evaluated parasitism of *Diadegma anurum* on eight cultivars of *Brassica oleracea* var. *botrytis*. In this study, the highest parasitism rate was observed by *D. anurum* that was recorded on Buris cultivar (19.92±1.06) and White cloud cultivar (16.20±1.49) and the lowest parasitism rate was observed on Snow crown cultivar (3.42) and SG cultivar (5.00) during the season. Population density of the cabbage aphid *Brevicoryne brassicae* (L.) and its parasitoids *Diaeretiella rapae* (M.) (Hymenoptera: Braconidae) was evaluated on various cauliflower cultivars in field condition by Jahan et al. (2013b) and it was found that the Smilla, Buris and SG cultivars has probably increase the efficiency of *D. rapae* on
B. brassica. It can be concluded that density of DBM was lowest on Buris cultivar and parasitoid activity of O. sokolowskii on this cultivar was more than other cultivars, and therefore the use of this cultivar is preferred than other cultivars.

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