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Influence of different host plant cultivars on nutritional indices of *Plutella xylostella* (Lepidoptera: Plutellidae)

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Abstract: The diamondback moth, *Plutella xylostella* (L.) is a serious and economically important pest of cruciferous crops worldwide. The nutritional indices of this pest on four host plants including two canola (SLM_{046} and RGS_{003}) and two cabbage cultivars (Green-Cornet and Glob-Master) were determined under laboratory conditions (25 ± 0.5 °C, 65 ± 5% RH and 16: 8 L: D h). The highest relative consumption rate (RCR) and relative growth rate (RGR) were recorded on RGS_{003} (95.68 ± 14.52 mg/mg/day) and SLM_{046} (0.382 ± 0.041 mg/mg/day), respectively. The efficiency of the conversion of ingested food (ECI) and efficiency of conversion of digested food (ECD) were significantly higher on SLM_{046} (2.298 ± 0.646 and 2.471 ± 0.719%, respectively). However, there was no significant difference among cultivars regarding approximate digestibility (AD) index. The highest feeding performance of the larvae of *P. xylostella* was found on SLM_{046}. The nutritional indices are appropriate tools in host plant resistance evaluation and they also could provide profound understanding of the behavioral and physiological bases of insect-host plant interactions.

Keywords: nutritional indices, canola, cabbage, *Plutella xylostella*

Introduction

The diamondback moth, *Plutella xylostella* (L.) (Lepidoptera: Plutellidae) is the most important pest of Brassicaceae crops in the world. Importance of *P. xylostella* is reflected in (i) being the most widely distributed of all the Lepidoptera (Talekar and Shelton, 1993;), (ii) its high reproductive potential (over 20 generations per year in tropics), (iii) lack or disruption of its natural enemies (Hui *et al*., 2010) and (iv) its genetic elasticity facilitating rapid development of resistance to chemical insecticides (Sayyed *et al*., 2004; Sarfraz *et al*., 2007; Ahmad *et al*., 2012). Insecticide application is the primary method of control of *P. xylostella*, but high tolerance to most of insecticides and associated environmental problems may result in outbreaks of the pest by destruction of its natural enemies (Ahmad *et al*., 2012). These drawbacks have increased interest in other control methods such as biological control and resistant cultivars of host plants. Therefore, the mentioned methods are useful and desirable tools in most pest management programs because they are effective and non-toxic to natural enemies, human and the environment (Haseeb *et al*., 2004; Xu *et al*., 2004; Fathipour and Sedaratian, 2013).

Study of biological, physiological and ecological characteristics of insect pests on different host plants is a way to recognize the host plant resistance to these herbivores (Sarfraz *et al*., 2007). The role of quality of herbivores' food in insect-plant relationship has been determined in some studies (David and Gardiner, 1962; Sheiker

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et al., 2001; Xue *et al*., 2010). The rates of food ingestion, growth and utilization efficiency are important components of herbivores' performance. From a nutritional point of view, utilization efficiency reflects the quality of food consumed (Naseri *et al*., 2010; Baghery *et al*., 2013).

Few studies are available regarding the nutritional indices of *P. xylostella*. Some of these studies have presented the effects of chinaberry extract (Chen *et al.,* 1996), antifeedants (Perera *et al.,* 2000) and neem-based insecticides (Ahmad *et al.,* 2012) on these indices. Chen *et al.,* (1996) showed that the food consumption was reduced at high concentrations (2 and 4%) of chinaberry fruit extract. Also, some antifeedants significantly decreased the food consumption of *P. xylostella* larvae (Perera *et al.,* 2000. Ahmad *et al.,* (2012) suggested that high concentrations (15 and 20 ppm) of Neemazal, one of the neem-based insecticides, significantly affected the nutritional indices of the larvae of *P. xylostella* by reducing consumption and utilization rate of available food.

Growth, development and reproduction of insects strongly depend on the quality and quantity of food consumed (Scriber and Slansky, 1981). This information could help to assess the crop loss properly and design a suitable integrated pest management (IPM) program to keep the population of a herbivorous pest below an economically important level. Determining the nutritional indices of an insect on a particular host is a tool for evaluating host plant resistance mechanisms that could improve pest management programs. In this study, the effects of different cultivars of host plants on the nutritional indices of *P. xylostella* were studied.

Materials and Methods

Insect and plants

Seeds of four different cultivars of two host plants including canola, *Brassica napus* L. (SLM_{046}, RGS_{003}) and cabbage, *Brassica oleracea var. capitata* (Green-Cornet, Glob-Master) were obtained from the Seed and Plant Improvement Institute (Karaj, Iran). These seeds were individually planted in the greenhouse of Tarbiat Modares University in plastic pots, without any fertilizers and pesticides. The leaves of cruciferous cultivars were used for experiments when the plants were 4 weeks old. The original population of *P. xylostella* was collected from the cabbage fields of University of Tehran (Karaj, Iran), during September 2010. The collected specimens were maintained in a growth chamber at 25 ± 0.5 °C, 65 ± 5% RH and 16: 8 h (L:D). The F_2 generation of *P. xylostella* was used in all experiments.

Feeding assays

Newly molted fourth instar larvae of *P. xylostella* were used to measure their nutritional indices on different host plants tested. The larvae were individually transferred into plastic containers (diameter: 10 cm, depth: 1.5 cm) with a hole on its top that was covered by fine mesh net for ventilation. The experiment was started with 20 replications per cultivar. Every 8 hours, the weights of the fourth instar larvae, food given, unconsumed food and feces produced were recorded until the pupal stage. To calculate the dry weight of the larvae, feces and leaves of each cultivar, extra specimens (10 specimens for each treatment) were weighed, oven-dried (until completely dried at 60 °C), and then re-weighed to establish a percentage of their dry weight. The nutritional indices were calculated based on the dry weights using the formulae presented in Waldbauer (1968) (Table 1).

Statistical analysis

Normal distribution of the data obtained from feeding assays was tested by Kolmogrov-Smirnov test. The data for the effects of different cultivars of cruciferous plants (set as completely randomized design) on nutritional indices were subjected to one-way analysis of variance (ANOVA) to determine the similarities or significant differences. Statistical differences among means were evaluated using Tukey test at $\alpha = 0.05$.

Results

Significant differences among host plants for larval weight, food consumed and feces produced by the fourth instar larvae of *P. xylostella* are presented in Table 2. The highest and lowest values of larval weight were on Green-Cornet (0.980 mg) and

Glob-Master (0.110 mg), respectively ($F = 107.39$; $df = 3, 60$; $P < 0.001$). Food consumed by the fourth instars were highest on Green-Cornet (48.08 mg) and lowest on Glob-Master (21.52 mg) ($F = 5.37$; $df = 3, 60$; $P < 0.03$). The amounts of feces produced ranged from 0.522 (RGS_{003}) to 1.184 mg (SLM_{046}) ($F = 3.39$; $df = 3, 60$; $P < 0.05$).

Different host plants affected the relative growth rate (RGR) of the larvae of *P. xylostella* (Table 3). The lowest and highest RGR values belonged to the larvae reared on Green-Cornet and SLM_{046}, respectively ($F = 11.62$; $df = 3, 59$; $P < 0.01$). The data on the effects of different host plants on the relative consumption rate (RCR) are given in Table 3. The RCR was significantly different among cultivars tested ($F = 13.57$; $df = 3, 59$; $P < 0.01$) and its value ranged from 95.68 mg/mg/day on RGS_{003} to 21.74 mg/mg/day on Green-Cornet. The efficiency of conversion of digested food (ECD) as the function of different cultivars of cruciferous plants is summarized in Table 3. Among all of the cultivars tested, the ECD was not significantly different except on SLM_{046} ($F = 4.67$; $df = 3, 59$; $P < 0.01$). The effects of different cruciferous cultivars on the conversion of ingested food efficiency (ECI) are indicated in Table 3. The highest value of ECI was related to the larvae reared on SLM_{046} and it was significantly different from other cultivars tested ($F = 4.93$; $df = 3, 59$; $P < 0.01$). As shown in Table 3, the fourth larval instar had no significant difference regarding approximate digestibility (AD) on different cultivars ($F = 2.28$; $df = 3, 59$; $P > 0.05$).

Table 1 The formulae of the nutritional indices calculated for *Plutella xylostella* (Waldbauer, 1968).

Abbreviation	Nutritional index	Formula
RCR	Relative consumption rate	$E/(A \times T)$
RGR	Relative growth rate	$P/(A \times T)$
AD	Approximate digestibility	$[(E-F)/E] \times 100$
ECI	Efficiency of conversion of ingested food	$(P/E) \times 100$
ECD	Efficiency of conversion of digested food	$[P/(E-F)] \times 100$

P = dry weight gain (mg), A = initial and final mean dry weights of the larvae during feeding period (mg), E = dry weight of food ingested (mg), T = duration of feeding period (days), F = the dry weight of feces produced (mg).

Table 2 Mean (+SE) larval weight of *Plutella xylostella*, food consumed and feces produced by fourth instar larvae on different cultivars.

Cultivars	Larval weight (mg)	Food consumed (mg)	Feces produced (mg)
SLM_{046}	0.786 ± 0.049b	35.23 ± 2.730ab	1.184 ± 0.207a
RGS_{003}	0.179 ± 0.009c	30.51 ± 4.061ab	0.522 ± 0.086b
Green-Cornet	0.980 ± 0.058a	48.08 ± 4.552a	0.928 ± 0.194ab
Glob-Master	0.110 ± 0.005c	21.52 ± 3.875b	0.713 ± 0.096ab

Means followed by the same letter within the same column are not significantly different (α = 0.05, Tukey).

Table 3 Nutritional indices (mean ± SE) of fourth instar larvae of *Plutella xylostella* on different cultivars

Cultivars	RCR (mg/mg/day)	RGR (mg/mg/day)	ECD (%)	ECI (%)	AD (%)
SLM_{046}	28.838 ± 2.325b	0.382 ± 0.0412a	2.471 ± 0.719a	2.298 ± 0.646a	95.867 ± 0.715a
RGS_{003}	95.685 ± 14.521a	0.335 ± 0.025a	0.563 ± 0.111b	0.539 ± 0.103b	97.557 ± 0.618a
Green-Cornet	21.743 ± 2.379b	0.139 ± 0.016b	0.808 ± 0.166b	0.782 ± 0.152b	97.866 ± 0.549a
Glob-Master	93.099 ± 15.749a	0.216 ± 0.027ab	0.387 ± 0.109b	0.356 ± 0.093b	95.321 ± 1.377a

Means followed by the same letters in the same columns are not significantly different (α = 0.05, Tukey). AD = approximate digestibility, ECI = efficiency of conversion of ingested food, ECD = efficiency of conversion of digested food, RCR = relative consumption rate, RGR = relative growth rate.

Discussion

Resistant cultivars are recognized as a key factor in IPM programs (Endo *et al*., 2007; Fathipour and Sedaratian, 2013). The quality and quantity of food consumed by a pest can affect its biological and physiological parameters (Nation 2000; Golizadeh *et al*., 2009). Recent demographic studies suggested SLM_{046} and Green-Cornet as susceptible cultivars and RGS_{003} and Glob-Master as resistant cultivars to *P. xylostella* (Soufbaf *et al*., 2010; Kianpour *et al*., 2013). The larvae of *P. xylostella* fed on the susceptible cultivars (SLM_{046} and Green-Cornet) had lower RCR values than those fed on the resistant ones (RGS_{003} and Glob-Master). The larvae fed on SLM_{046} and Green-Cornet had more weight with lower amount of food consumed. On the other hand, the larvae fed on RGS_{003} and Glob-Master consumed more food to reach suitable weight because these host plants may have not good quality or the values of nutritional elements were not enough (Slansky and Scriber, 1982). The highest RGR on SLM_{046} showed its high quality and suitability as a host plant for the larvae of *P. xylostella*.

More than 95% of amount of total food consumed by the fourth instar larvae of *P. xylostella* was digested. It might be linked to high ability of digestive enzymes of the larvae to digest food consumed. It seems that *P. xylostella* has a good conformity with the range of host plants and high ability to digest eaten food. On the other hand, about 2% of food eaten was converted to biomass on susceptible cultivar (SLM_{046}). Indeed, the high amount of AD could be explained in two ways: (i) increase in RGR due to energy of digested food or (ii) repelling most of eaten food as feces. The data showed that the second explanation is more acceptable, showing that a great percentage of eaten food was converted to feces (Xue *et al*., 2010). Considering ECD and ECI values, about 2% of the ingested food was converted to biomass in the larvae that were fed on SLM_{046}. The lower ECI on other cultivars might be related to decrease in efficiency of converting the ingested food into growth. The larvae feeding on SLM_{046} had the highest value of ECD, showing that these larvae have more efficiency for the conversion of digested food to their biomass. Any changes in ECI and ECD values represent the proportion of ingested food converted into energy (Koul *et al*., 2004; Baghery *et al*., 2013).

Analysis of the nutritional indices can lead to understand the behavioral and physiological bases of insect- plant interactions (Lazarevic and Peric-Mataruga, 2003). Lower fitness of *P. xylostella* on some cultivars may depend on presence of some secondary phytochemicals in the cruciferous plants, e.g. glucosinolate (GS), or may depend on the absence of some primary nutrients such as nitrogen, which is necessary for growth and development of insect herbivores (Gols *et al*., 2008; Soufbaf *et al*., 2012). Some studies showed that high level of glucosinolates is the main factor that reduces the performance of *P. xylostella* (Li *et al*., 2000; Gols *et al*., 2008; Soufbaf *et al*., 2012). On the other hand, Soufbaf *et al*., (2012) reported that *P. xylostella* developed poorly on the resistant cultivar of canola, which has lower value of nitrogen in its leaf tissues.

In conclusion, this study revealed that among different measures to be applied for evaluating host plants resistance in IPM programs, the nutritional indices could have an important place and they might be used in combination with other methods for getting more reliable results. This conclusion has been supported by comparing the results of the nutritional indices obtained in this study with the life table parameters and digestive enzymes of *P. xylostella* (unpublished data) in which in most cases they were in conformity with one another.

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تأثیر میزبان‌های مختلف گیاهی روی شاخص‌های تغذیه‌ای شب‌پره پشت‌الماسی *Plutella xylostella* (Lepidoptera: Plutellidae)

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چکیده: شب‌پره پشت‌الماسی *Plutella xylostella* L. یکی از آفات مخرب محصولات خانواده کلمیان در جهان است. در این مطالعه، شاخص‌های تغذیه‌ای لاروهای شب‌پره پشت‌الماسی روی دو میزبان گیاهی کلزا (ارقام SLM_{046} و RGS_{003}) و کلم پیچ (ارقام Green-Cornet و Glob-Master) در دمای ۰/۵ ± ۲۵ درجه سلسیوس، رطوبت نسبی ۵ ± ۶۵ درصد و دوره نوری ۱۶ ساعت روشنایی و ۸ ساعت تاریکی مورد مطالعه قرار گرفت. بیشترین میزان نرخ مصرف نسبی (RCR) و نرخ رشد نسبی (RGR) لاروهای سن چهارم شب پره پشت‌الماسی روی RGS_{003} به‌میزان ۱۴/۵۲ ± ۹۵/۶۸ (میلی‌گرم/میلی گرم/روز) و SLM_{046} به‌میزان ۰/۰۴۱ ± ۰/۳۸۲ (میلی‌گرم/میلی‌گرم/روز) به‌دست آمد. بالاترین میزان کارایی تبدیل غذای خورده شده (ECI) و کارایی تبدیل غذای هضم شده (ECD) (به‌ترتیب ۰/۶۴۶ ± ۲/۲۹۸ و ۰/۷۱۹ ± ۲/۴۷۱ درصد) روی رقم SLM_{046} مشاهده شد. میزان شاخص تقریبی هضم‌شوندگی (AD) تفاوت معنی‌داری روی ارقام مختلف کلزا و کلم نداشت. این نتایج نشان داد که لاروهای شب‌پره پشت‌الماسی کارایی تغذیه‌ای بهتری را روی رقم SLM_{046} دارند. تجزیه و تحلیل شاخص‌های تغذیه‌ای می‌تواند در درک ابعاد مختلف روابط متقابل حشرات-گیاه میزبان مؤثر باشد.

واژگان کلیدی: شاخص‌های تغذیه، *Plutella xylostella*، کلم، کلزا