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Performance Evaluation of *Spodoptera exigua* (Lepidoptera: Noctuidae) Larvae on 10 Sugar Beet Genotypes Using Nutritional Indices

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ABSTRACT

The aim of this study was to evaluate the effect of ten different sugar beet genotypes on nutritional indices of the beet army worm, *Spodoptera exigua* (Hübner) (Lep.: Noctuidae) at 25±1°C, 60±5% *RH* and a photoperiod of 16:8 (L: D) hour. The sugar beets evaluated in this study included two sugar beet cultivars (HM 1339 RZ and SBSI006), five populations (SB26, SB27, SB29, SB33, SB34), one hybrid (7112*SB36)*Sh-1-HSF-5 and two lines (FC 301 and FC 220). Fourth instar larvae reared on (7112*SB36)*Sh-1-HSF-5 showed the highest Relative Growth Rate (RGR) of 0.31 mg mg^{-1} day^{-1}, Relative Consumption Rate (RCR) of 4.79 mg mg^{-1} day^{-1} and Approximate Digestibility (AD) value of 94.35% compared with the other host plants. The lowest value of *RCR* (0.81 mg mg^{-1} day^{-1}) was on SBSI006. The Efficiency of Conversion of Ingested food (ECI) was varied from 1.80% on FC 220 to 9.14% on SB34. The highest *AD* value of fifth instar (92.63%) was on (7112*SB36)*Sh-1-HSF-5 and the lowest value of this index was recorded on SB27 (83.71%). The highest *AD* value of whole larval instars was noted in (7112*SB36)*Sh-1-HSF-5 (93.73%). The lowest value of *RCR* (1.78 mg mg^{-1} day^{-1}) was found on SB27. The heaviest pre-pupa (81.01 mg), pupa (72.55 mg) and wet adults (19.14 mg) of beet armyworm were recorded on (7112*SB36)*Sh-1-HSF-5. The results indicated that (7112*SB36)*Sh-1-HSF-5 was the most suitable host for *S. exigua* that should be considered in cultivation or breeding programs.

Keywords: Antibiosis, Beet armyworm, Food consumption, Insect weight.

INTRODUCTION

The beet armyworm, *Spodoptera exigua*, is an important pest in the tropical and semitropical areas of the world that originates from Southeast Asia (Liburd *et al*., 2000). This phytophagouspest has a wide host range and feeds on more than 170 plant species including sugar beet (Zhang *et al.*, 2011; Goodarzi *et al.*, 2015). Sugar beet (*Beta vulgaris* L.) is an important crop for the extraction of sugar and is also an efficient alternative biofuel as opposed to fossil fuels for energy production (Hinkova and Bubnik, 2001). On sugar beet, the larvae intense feeding on leaves can cause significant yield loss. In addition, their feeding on the beet roots near the soil opens the way for the entry of pathogens which cause heavy loss.

Widespread use of chemical pesticidesas the main control tactic against *S. exigua* caused resistance to a wide range of insecticides including organophosphates, carbamates, pyrethroids and some novel insecticides. This has led to the pest outbreaks and harvest loss (Che *et al.*, 2013). Therefore, there is a critical need to

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work on other control methods to design an eco-friendly IPM program. A fundamental element of an IPM program for any crop is to investigate the degree of resistance in different cultivars, as this can enhance the efficacy of biological and chemical procedures (Soufbaf *et al*., 2010).

Resistant plants have complex direct and indirect defensive pathways. Similarly, insects can adopt multidimensional physiological and behavioral compensatory responses. For example, insects can increase the rate of protein consumption, if they face proteins which are less digestible due to the presence of proteinase inhibitors. One of the most popular techniques for the study of insect-plant challenge is nutritional indices containing pre- and post-ingestive factors affecting growth, consumption and utilization efficacy (Rayapuram *et al.*, 2006). One of the practical applications of nutritional indices is to compare the insect's performance on different host plants in order to determine the host plants uitability for growth and development of different insect pests (Klein and Kogan, 1974).

Sugar beet is a relatively young crop with only about 300 years history, possessing a narrow genetic base. Besides, the resistant mechanisms are mainly controlled by multiple genes which are simply broken under heavy infestation, so there are a few commercially known sugar beet resistant cultivars (Karimi-Malati *et al.*, 2012). Despite the economic impact of *S. exigua* and sugar beet, there is no information about the nutritional indices of this pest on sugar beet genotypes, although some related studies have been conducted on the effects of host plants, apart from sugar beet varieties, on nutritional indices of this noctuid pest (Pourghasem, 2011; Mehrkhou, 2013). Therefore, the present study provides new information on the nutritional indices of *S. exigua*on various sugar beet genotypes and germplasms screening for resistant sources identification.

MATERIALS AND METHODS

Plants

Seeds of two sugar beet cultivars (HM 1339 RZ and SBSI006), five populations (SB26, SB27, SB29, SB33, SB34), one hybrid [(7112*SB36)*Sh-1-HSF-5] and two lines (FC 301 and FC 220) were obtained from Sugar Beet Seed Institute, Karaj, Iran. Selection of these genotypes was performed regarding our previous study comparing resistance of 24sugar beet genotypes to *S. exigua* using life table parameters (Talaee *et al.*, 2017). SB26, SB27, SB29, SB33 and SB34 are rhizomania resistant populations that can be used in seed production process. Two lines (FC 301 and FC 220) and one hybrid [(7112*SB36)*Sh-1-HSF-5] were picked for the experiment, which are rhizomania resistant genotypes that have been produced and processed for cultivar registrations in Sugar Beet Seed Institute (SBSI). SBSI006 is a commercial cultivar in Iran and has been produced in SBSI via recurrent selection process. On the other hand, HM1339RZ is an imported commercial cultivar. Plants were grown from seeds in 24 cm diameter plastic pots in a greenhouse (25±5°C, 60±10% RH and natural photoperiod) of Experimental Station of the Faculty of Agriculture, Isfahan University of Technology, Isfahan, Iran. During the experiments, no pesticide or fertilizer was used**.**

Insects

Specimens of *S. exigua* larvae were collected from sugar beet fields in Isfahan, Iran. Stock culture was initiated on Lettuce (*Lactuca sativa*) under laboratory conditions at 25±1°C, 60±5% *RH* and a photoperiod of 16:8 (L: D). Adults of this colony were kept in plastic containers (17 cm diameter and 16 cm height) for oviposition. A small cotton wick soaked in 10% honey solution was placed in oviposition jars for adult feeding.

Then, offspring of this colony were reared separately on leaves of sugar beet genotypes. The F2 generation of beet army worm was used in all experiments.

Experiments

Newly hatched larvae were collected from the related colony and were reared until they reached the fourth instar. From the fourth instar, 20 larvae were individually transferred into plastic containers (5 cm in diameter and 8 cm in height) with a hole on their top which was covered with a fine mesh net for ventilation. The fresh weights of larvae, provided food, unconsumed food and produced feces were daily recorded until the adult emergence. Feces were separated from the leaves and dishes with a soft brush and were weighed. 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 (48 hours at 60°C), and then reweighed to calculate a percentage of their dry weights. The nutritional indices were calculated based on the dry weights using the formulae presented in Waldbauer (1968) and Huang and Ho (1998). Approximate Digestibility (%) [AD= (E-F)/E)×100], Relative Consumption Rate (mg mg^{-1} day^{-1}) [RCR= E/(A×T)], Relative Growth Rate (mg mg^{-1} day^{-1}) [RGR= P/(A×T)], Efficiency of Conversion of Ingested food (%) [ECI= (P/E)×100] and Efficiency of Conversion of Digested food (percent) [ECD= (P/(E-F))×100] , where *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).

Statistical Analysis

Data were checked for normality prior to analysis by Kolmogorov-Smirnov test. Statistical processing of results was performed by standard methods using the statistical software SPSS version 23.0 (SPSS, 2007). If significant differences were detected, means were compared using Tukey test at α= 0.05. A dendrogram of sugar beet genotypes based on nutritional indices of *S. exigua* whole larval instars, was constructed after cluster analysis by Ward's method using SPSS 23.0 statistical software.

RESULTS

The results of the nutritional indices of fourth, fifth, and whole larval instars of *S. exigua* are presented in Tables 1, 2 and 3. The indices of fourth instars of *S. exigua* were significantly different on sugar beet genotypes (Table 1). The larvae reared on (7112*SB36)*Sh-1-HSF-5 showed the highest values of *RCR* and *RGR* (4.79±0.74 and 0.31±0.05 mg/mg/day, respectively). The lowest values of *RGR* (0.03±0.01 mg mg^{-1} day^{-1}) and *RCR* (0.81±0.03 mg mg^{-1} day^{-1}) were recorded on SB27 and SBSI006, respectively. The efficiency of conversion of ingested food varied from 1.80±0.2 to 9.14±1.91% on FC 220 and SB34, respectively. The highest *ECD* (13.18±3.33%) and the lowest *AD* (85.98±1.67%) values were on SB34.

Nutritional parameters of fifth instars of beet armyworm were found to be significantly different based on the sugar beet genotypes on which individuals were reared (Table 2). The highest *AD* value of fifth instars (92.63±0.25%) was on (7112*SB36)*Sh-1-HSF-5 and the lowest value of this parameter was recorded on SB27 (83.71±0.81%). The highest value of *ECI* produced by larvae of *S. exigua* was reared on SB27 (35.23±1.63%) whilst the lowest *ECI* value belonged to (7112*SB36)*Sh-1-HSF-5(17.11±1.37%).
The highest RCR and RGR were obtained on SB27 (2.04±0.20 and 0.71±0.05 mg mg^{-1} day^{-1}, respectively) but the lowest *RCR* and *RGR* were on SBSI006 (0.54±0.02 and 0.17±0.02 mg mg^{-1} day^{-1}, respectively).

Table 1. Nutritional indices of fourth instars of *Spodoptera exigua* on different sugar beet genotypes.

Genotype	*ECI* (%) [a]	*AD* (%) [b]	*ECD* (%) [c]	*RCR* [d] (mg mg^{-1} day^{-1})	*RGR* [e] (mg mg^{-1} day^{-1})
SB26	6.20 ± 0.31ab [f]	89.11 ± 0.73bc	7.08 ± 0.18b	2.16 ± 0.10bcd	0.16 ± 0.01bc
SB27	1.84 ± 0.25c	92.68 ± 0.35ab	2.11 ± 0.3b	1.63 ± 0.04bcde	0.03 ± 0.01d
SB29	6.32 ± 1.16ab	94.19 ± 0.53a	7.37 ± 1.51b	2.77 ± 0.21b	0.19 ± 0.04b
SB33	6.19 ± 0.69ab	88.29 ± 1.09bc	7.01 ± 0.76b	2.48 ± 0.19bc	0.16 ± 0.02bc
SB34	9.14 ± 1.91a	85.98 ± 1.67c	13.18 ± 3.33a	1.13 ± 0.17de	0.07 ± 0.01cd
FC 301	3.53 ± 0.67bc	90.52 ± 0.57ab	4.02 ± 0.75b	1.60 ± 0.24bcde	0.07 ± 0.02cd
FC 220	1.80 ± 0.2c	89.01 ± 1.67bc	2.34 ± 0.19b	1.21 ± 0.16cde	0.04 ± 0.00d
(7112*SB36)*Sh-1-HSF-5	5.22 ± 0.61abc	94.35 ± 0.27a	5.54 ± 0.64b	4.79 ± 0.74a	0.31 ± 0.05a
SBSI006	4.04 ± 0.38bc	90.80 ± 0.91ab	4.35 ± 0.39b	0.81 ± 0.03e	0.04 ± 0.01d
HM 1339 RZ	6.06 ± 1ab	93.64 ± 0.88a	6.58 ± 1.09b	2.33 ± 0.24bcd	0.13 ± 0.03bcd
F (*df*= 9, 190)	6.73	8.18	6.19	16.28	13.9
P (Tukey)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01

[a] Efficiency of Conversion of Ingested food; [b] Approximate Digestibility; [c] Efficiency of Conversion of Digested food; [d] Relative Consumption Rate, [e] Relative Growth Rate. [f] The means followed by different letters in the same columns are significantly different (*P*< 0.05, Tukey's test).

Table 2. Nutritional indices of fifth instars of *Spodoptera exigua* on different sugar beet genotypes.

Genotype	*ECI* (%) [a]	*AD* (%) [b]	*ECD* (%) [c]	*RCR* [d] (mg mg^{-1} day^{-1})	*RGR* [e] (mg mg^{-1} day^{-1})
SB26	22.55 ± 2.01bcd [f]	88.65 ± 0.6bc	21.44 ± 1.06de	1.15 ± 0.08abc	0.25 ± 0.03cd
SB27	35.23 ± 1.63a	83.71 ± 0.81d	46.98 ± 3.88a	2.04 ± 0.20a	0.71 ± 0.05a
SB29	19.68 ± 0.72cd	89.90 ± 0.6abc	21.98 ± 0.89cde	1.61 ± 0.28ab	0.34 ± 0.07bcd
SB33	23.47 ± 1.37bcd	87.81 ± 0.35bc	26.79 ± 1.62bcde	1.64 ± 0.21ab	0.37 ± 0.04bcd
SB34	25.22 ± 2.29bcd	86.71 ± 0.97cd	33.43 ± 3.92bc	1.44 ± 0.17abc	0.39 ± 0.07bcd
FC 301	30.13 ± 1.69ab	87.24 ± 0.39bc	33.76 ± 2.06b	1.93 ± 0.30ab	0.50 ± 0.07ab
FC 220	26.02 ± 1.88bc	87.08 ± 1.32bcd	28.33 ± 3.56bcde	1.03 ± 0.16bc	0.42 ± 0.03bc
(7112*SB36)*Sh-1-HSF-5	17.11 ± 1.37d	92.63 ± 0.25a	18.70 ± 1.6e	1.29 ± 0.23abc	0.24 ± 0.03cd
SBSI006	27.89 ± 2.56ab	90.40 ± 0.93ab	30.70 ± 2.87bcd	0.54 ± 0.02c	0.17 ± 0.02d
HM 1339 RZ	23.03 ± 1.8bcd	86.57 ± 0.66cd	26.52 ± 2.24bcde	1.69 ± 0.20ab	0.44 ± 0.08bc
F (*df*= 9, 190)	8.83	10.72	9.73	4.97	9.05
P (Tukey)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01

[a] Efficiency of Conversion of Ingested food; [b] Approximate Digestibility; [c] Efficiency of Conversion of Digested food; [d] Relative Consumption Rate, [e] Relative Growth Rate. [f] The means followed by different letters in the same columns are significantly different (*P*< 0.05, Tukey's test).

The nutritional indices for whole instars of beet armyworm varied significantly on different sugar beet genotypes (Table 3). The highest *AD* value of the whole instars was noted on (7112*SB36)*Sh-1-HSF-5 (93.73±0.18%) whilst the lowest value of *RCR* (71.25±2.73 mg mg^{-1} day^{-1}) was found on SB27. On the other hand, the highest and lowest values of *ECI* were on SB27 (24.65±1.25%) and SB26 (11.78±0.29%). Amongst the different genotypes of sugar beet, the highest values of *RCR* and *RGR* were on SB29 (5.71±0.07 and 0.87±0.03 mg mg^{-1} day^{-1}, respectively), and the lowest *RGR* was on SB26 (0.29±0.02 mg mg^{-1} day^{-1}). The lowest ECD of the *S. exigua* whole instars was recorded on (7112*SB36)*Sh-1-HSF-5 (13.74±1.17%).

Our findings on pre-pupa, pupa and adults' weight of *S. exigua* demonstrated significant difference among various sugar beet genotypes (Table 4). The heaviest pre-pupa (81.01±3.35 mg), pupa (72.55±2.81 mg) and wet adults' weight (19.14 ± 1.42 mg) of beet armyworm were recorded on (7112*SB36)*Sh-1-HSF-5. The lightest pre-pupa (44.58±6.8 mg) and pupa (37.52±6.8 mg) were recorded on SB29 and the lightest wet adult's weight was on FC 301(12.61±0.89 mg). As shown in Table 4, there was no significant difference between dry adult weights of the tested genotypes.

The significant variations of total food consumed and total feces produced by larvae of *S. exigua* on different host plants are demonstrated in Table 4. Total food consumed by the larvae was the highest on (7112*SB36)*Sh-1-HSF-5 (1991.88±73.57mg) and lowest on SB27 (1110.30±60.01 mg). The larvae reared on SB33 produced the highest feces weight (195.45±11.57 mg) and the larvae reared on (7112*SB36)*Sh-1-HSF-5 had the lowest (129.14±5.16 mg) amounts of feces.

The dendrogram of nutritional indices of whole instars of *S. exigua* reared on different genotypes is plotted in Figure 1. This dendrogram represents two distinct clusters which are labeled A (including subclusters A1 and A2) and B. Subcluster A1 is a susceptible group and included (7112*SB36)*Sh-1-HSF-5, SBSI006 and

Table 3. Nutritional indices of whole instars of *Spodoptera exigua* on different sugar beet genotypes.

Genotype	*ECI* (%) [a]	*AD* (%) [b]	*ECD* (%) [c]	*RCR* [d] (mg mg^{-1} day^{-1})	*RGR* [e] (mg mg^{-1} day^{-1})
SB26	11.78 ± 0.29f [f]	89.83 ± 0.6a	14.38 ± 0.91e	2.10 ± 0.07de	0.29 ± 0.02f
SB27	24.65 ± 1.25a	88.73 ± 0.56ab	28.46 ± 1.6a	1.78 ± 0.07e	0.43 ± 0.02cde
SB29	14.34 ± 0.63def	90.89 ± 0.73a	15.87 ± 0.78de	5.71 ± 0.07a	0.87 ± 0.03a
SB33	16.43 ± 0.76cde	89.28 ± 0.36ab	18.42 ± 0.88cde	4.64 ± 0.11b	0.72 ± 0.02b
SB34	19.00 ± 1.55bc	87.76 ± 0.47ab	21.80 ± 1.84bc	2.11 ± 0.09de	0.37 ± 0.03def
FC 301	21.10 ± 0.9ab	88.16 ± 0.42ab	23.73 ± 1.06ab	2.22 ± 0.06de	0.47 ± 0.02cd
FC 220	21.32 ± 1.17ab	82.61 ± 4.39b	23.17 ± 1.34bc	2.26 ± 0.21de	0.49 ± 0.06cd
(7112*SB36)*Sh-1-HSF-5	12.80 ± 1.06ef	93.73 ± 0.18a	13.74 ± 1.17e	3.26 ± 0.08c	0.41 ± 0.03cdef
SBSI006	18.16 ± 0.55bcd	91.29 ± 0.72a	20.05 ± 1bcd	3.02 ± 0.18c	0.51 ± 0.02c
HM 1339 RZ	15.57 ± 0.65cdef	91.55 ± 0.54a	18.07 ± 0.42cde	2.39 ± 0.18d	0.33 ± 0.01ef
F (df= 9, 190)	18.49	4.09	15.69	92.2	30.63
P (Tukey)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01

[a] Efficiency of Conversion of Ingested food; [b] Approximate Digestibility; [c] Efficiency of Conversion of Digested food; [d] Relative Consumption Rate, [e] Relative Growth Rate. [f] The means followed by different letters in the same columns are significantly different (P< 0.05, Tukey's test).

Table 4. The mean (±SE) weights of pre-pupa, pupa, adult, food consumed and feces of *Spodoptera exigua* on different sugar beet genotypes.

Genotype	PP (mg) [a]	P (mg) [b]	WA (mg) [c]	DA (mg) [d]	FC (mg) [e]	FP (mg) [f]
SB26	66.35 ± 3.65abc [g]	61.30 ± 3.47ab	18.11 ± 0.72ab	11.95 ± 0.45a	1384.77 ± 60.07de	137.49 ± 8.02b
SB27	66.44 ± 3.51abc	56.82 ± 1.94b	14.59 ± 1.66ab	9.12 ± 0.66a	1110.30 ± 60.01e	141.37 ± 12.5b
SB29	44.58 ± 6.8d	37.52 ± 6.8c	17.95 ± 1.63ab	10.29 ± 1.11a	1832.01 ± 91.81abc	159.88 ± 11.72ab
SB33	66.71 ± 1.7abc	62.88 ± 2.21ab	17.71 ± 1.55ab	11.62 ± 0.76a	1764.61 ± 86.26abc	195.45 ± 11.57a
SB34	48.00 ± 8.53cd	54.06 ± 2.92b	16.35 ± 1.38ab	10.95 ± 0.84a	1284.31 ± 80.15de	152.66 ± 7.58ab
FC 301	71.20 ± 3.56ab	65.01 ± 3.56ab	12.61 ± 0.89b	11.73 ± 0.86a	1568.28 ± 64.36cd	167.41 ± 12.84ab
FC 220	65.39 ± 2.47abcd	64.00 ± 2.39ab	14.30 ± 1.1ab	11.28 ± 0.89a	1588.44 ± 96.71bcd	140.96 ± 6.54b
(7112*SB36)*Sh-1-HSF-5	81.01 ± 3.35a	72.55 ± 2.81a	19.14 ± 1.42a	11.85 ± 0.87a	1991.88 ± 73.57a	129.14 ± 5.16b
SBSI006	56.11 ± 3.48bcd	54.85 ± 2.92b	13.89 ± 0.78ab	8.27 ± 0.24a	1817.85 ± 50.93abc	158.45 ± 15.03ab
HM 1339 RZ	70.81 ± 4.87ab	55.99 ± 2.35b	13.93 ± 1.95ab	12.08 ± 1.38a	1944.42 ± 127.66ab	160.50 ± 11.32ab
F (*df*= 9, 190)	5.74	7.48	2.74	2.28	12.87	3.14
P (Tukey)	< 0.01	< 0.01	< 0.01	**> 0.05**	< 0.01	< 0.01

[a] Per-pupa, [b] Pupa, [c] Wet Adult weight., [d] Dry Adult weightm, [e] Dry weight of Food Consumed, [f] Dry weight of Feces Produced;, [g] The means followed by different letters in the same columns are significantly different (*P*< 0.05, Tukey's test).

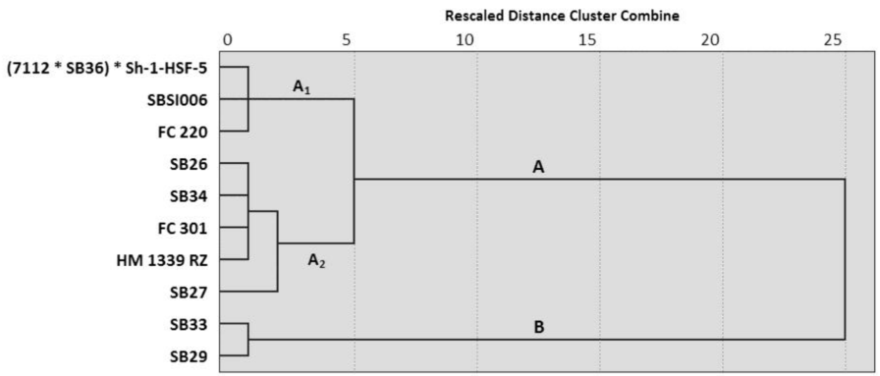

Figure1. Dendrogram of different sugar beet genotypes based on nutritional indices of *Spodoptera exigua* reared on different sugar beet genotypes.

FC 220. Subcluster A2 includes HM 1339 RZ, SB27, SB34, FC 301and SB26 and is a partially resistant group. Cluster B (SB33 and SB29) can be categorized as an intermediate group.

DISCUSSION

Choosing beneficial crop varieties, such as those with pest resistance, has always been a cornerstone of IPM programs. Resistance is the consequence of heritable plant features which can lead to a relatively less damageable plant. One of the techniques to identify the resistance to insects is to screen the germplasms by monitoring food consumption and utilization (Sharma, 2008; Soleimannejad *et al.,* 2010).

Significant differences were found within the nutritional indices of *S. exigua* reared on tested sugar beet genotypes, suggesting different nutritional quality of these genotypes. *ECI* is a common index of insects' ability to use the consumed food for growth and development. *ECD* is an index of the efficiency of conversion of digested food into growth (Naseri *et al.,* 2010). *RGR* is the rate of increase in weight of insect body in a unit time period, whereas RCR is the quantity of a food ingested per unit of insect body weight per time unit. Suitability of host plant can influence the duration of the developmental period (Hwang *et al.*, 2008), which is an effective factor for RGR and RCR calculation.

The results of the fourth instars showed that the larvae that fed on SB34 had the highest *ECI* and *ECD* and those reared on FC 220 had the lowest *ECI*. Surprisingly, the lowest *AD* of the fourth instars was recorded on SB34, indicating that more intake does not necessarily mean more digestion. Different factors such as secondary biochemicals can cause lower digestibility which leads to a low growth rate despite consumption of a large quantity of food. Digestibility reducers decrease the nutritional quality of host plants for consumers by preventing availability to nitrogen and other growth limiting resources (Price *et al.,* 2011; Panizzi and Parra, 2012). Fourth instars reared on (7112*SB36)*Sh-1-HSF-5 had the highest AD, RGR and RCR values which reveals the susceptibility of this genotype to *S. exigua* larvae in this age.

According to our results, when the fourth instars were included in the nutritional trials, *RGR* and *RCR* were consistently higher on (7112*SB36)*Sh-1-HSF-5. However, when fifth instar larvae were used, the maximum values were on SB27. Furthermore, the highest value of fifth instars' *AD* belonged to (7112*SB36)*Sh-1-HSF-5, but the highest fourth instars' *AD* was recorded on SB29. These observed shifts in preference by *S. exigua* could be explained by variation in nutritional requirements of the *S. exigua* during its development. In other words, changes of preferred genotypes (nutritional indices) in different larval instars may be related to the effect of ontogenetic shifts on the diet choice (Stockhoff, 1993).

Among different sugar beet genotypes, the highest *AD* and the lowest *ECD* of whole instars was found on (7112*SB36)*Sh-1-HSF-5. This can be explained by the highest amount of food consumed and the least amount of faeces produced by beet armyworm larvae reared on this hybrid in comparison to other ones. This hybrid produced the heaviest pre-pupae (81.01±3.35 mg) and pupae (72.55±2.81 mg) compared to other genotypes. These values are higher than the highest ones reported by Mehrkhou (2013) on the soybean variety Williams (Prepupa: 60±3.1 and Pupa: 74±3 mg) and Pourghasem (2011) on the canola varieties Okapi (Prepupa: 36.45±2.14 mg) and Opera (Pupa: 34.97±0.97 mg). Pupal weight is an indicator of adult fitness which has a direct correlation with adult fecundity and longevity (Greenberg *et al.,* 2001). These results reinforce the hypothesis that (7112*SB36)*Sh-1-HSF-5 is a more suitable genotype for *S. exigua* larvae compared to others.

For the whole instars, the population SB26 showed the lowest *ECI* and *RGR* values, this may be due to the presence of secondary biochemicals or inadequate nutritional components. Whole instars data demonstrated that more than 94% of food consumed by sugar beet larvae reared on (7112*SB36)*Sh-1-HSF-5 was digested. This value for larvae reared on FC 220, was only 75%. This may be due to a lower ability of digestive enzymes of the larvae in one genotype compared to other genotypes (Kianpour *et al.,* 2014). Considering *ECD* and *ECI* values, about 25% of the ingested food was converted to biomass in the larvae that were fed on SB27. The lower *ECI* on other genotypes might be related to decrease in efficiency of transforming the ingested food into growth. High *ECI* and *ECD* values on SB27 were followed by low *RCR*. The inverse correlation between *RCR* and *ECI* could have two theories. Firstly, when the larvae consumes less food, there is a slow food transition via the digestive system, therefore, it can be converted thoroughly and used by the insects. Secondly, insects can require less special food simply due to their capability of converting it more efficiently and thus in turn do not need to consume large quantities of that food to reach optimum levels of growth (Barbosa and Greenblatt, 1979; Hemati *et al.,* 2012; Kouhi *et al.,* 2014).

On the whole, the largest indices indicate a greater nutritional suitability; however, the presence of allelochemicals, or even the interaction between nutrients and allelochemicals, may cause erroneous explanation of data. Therefore it is vital to link the index values obtained with different biological and behavioural data. In this case, alternative methods, such as cluster analysis should be used (Panizzi and Parra, 2012). As dictated by the results of the cluster analysis, grouping amongst each cluster might be due to a high level of physiological resemblance of sugar beet genotypes, whereas the separate clusters show significant variability in physiological features (Naseri *et al.,* 2010). Analysis of the nutritional indices of *S. exigua* on different sugar beet genotypes showed sub cluster A1 genotypes were the most appropriate and sub cluster A2 genotypes were the least appropriate host for *S. exigua*, whereas the genotypes in cluster B had an intermediary status.

The results related to (7112*SB36)*Sh-1-HSF-5 and FC 301 (as appropriate and inappropriate host plants, respectively) are in accordance with the previous study for screening resistance sources to *S. exigua* in sugar beet genotypes using life table parameters (Talaee *et al.,* 2017). The finding of the study on the 24 sugar beet genotypes indicated that the highest and lowest life time Fecundity per female (F), the intrinsic rate of increase (*r*) and finite rate of increase (λ) were on (7112*SB36)*Sh-1-HSF-5 and FC 301, respectively, which is consistent with the current research.

Based on our findings in this study, the nutritional indices can play an important role in evaluation of the host plants resistance and their combination with other techniques has much concern in the present scenario. Different factors such as nutritional content, secondary substances of the host and the capability of food digestion and assimilation by an insect have been proven to affect host suitability for growth and development of phytophagous pest. In order to further explore the insect-plant interactions, more studies involving extraction and identification of phytochemicals, are required to address the potential of host plant preferences.

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ارزیابی کارایی لاروهای *Spodoptera exigua* (Lepidoptera: Noctuidae) روی ده ژنوتیپ چغندر قند با استفاده از شاخص های تغذیه ای

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چکیده

پژوهش حاضر با هدف ارزیابی اثر ۱۰ ژنوتیپ چغندر قند روی شاخص های تغذیه ای کرم برگخوار چغندر *Spodoptera exigua* (Hübner) در دمای ۱±۲۷ درجه سلسیوس و رطوبت نسبی ۵±۶۰ درصد با دوره نوری ۱۶ ساعت روشنایی و ۸ ساعت تاریکی انجام شد. ژنوتیپ های مورد مطالعه شامل دو رقم (HM 1339 RZ وSBSI006)، پنج توده (SB26، SB27،SB29، SB33 و SB34)، یک هیبرید (7112*SB36)*Sh-1-HSF-5)) و دو لاین (FC301 وFC220) بودند. لاروهای سن چهار پرورش یافته روی 7112*SB36)*Sh-1-HSF-5)بیشترین نرخ رشد نسبی (RGR: ۰/۳۱میلی گرم/ میلی گرم/ روز)، نرخ مصرف نسبی (RCR:۴/۷۹میلی گرم/ میلی گرم/ روز) و هضم شوندگی (AD:۹۴/۳۵) را نشان دادند و کمترین مقدار نرخ مصرف نسبی (RCR:۰/۸۱میلی گرم/ میلی گرم/ روز) روی SBSI006 محاسبه شد. نتایج نشان داد که بیشترین (۹/۸۰درصد) و کمترین (۱/۱۴درصد) بازدهی تبدیل غذای بلعیده شده (ECI) به ترتیب به ژنوتیپ هایSB34 و FC 220مربوط بود. بیشترین مقدار شاخص هضم شوندگی لاروهای سن پنجم (۹۲/۶۳درصد) روی 7112*SB36)*Sh-1-HSF-5) و کمترین مقدار این شاخص (۸۳/۷۱درصد) روی SB27 مشاهده شد. نتایج نشان داد که بیشترین شاخص هضم شوندگی مربوط به کل دوره لاروی (۹۳/۷۳ درصد) به7112*SB36)*Sh-1-HSF-5) و کمترین مقدار نرخ مصرف نسبی این دوره (۱/۷۸میلی گرم/ میلی گرم/ روز) به تودهSB27 تعلق داشته است. وزن تر حشرات کامل (۱۹/۱۴ میلی گرم)، شفیره ها (۷۲/۵۵ میلی گرم) و پیش شفیره های (۸۱/۰۱ میلی گرم) حاصل از لاروهای پرورش یافته روی 7112*SB36)*Sh-1-HSF-5) بیشتر از سایر ژنوتیپ ها بود. بر اساس این تحقیق، در بین ژنوتیپ های مورد مطالعه، هیبرید 7112*SB36)*Sh-1-HSF-5) مناسب ترین میزبان برای کرم برگخوار چغندر محسوب می شود.