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Vol. 8(16), pp. 1528-1533, 2 May, 2013
DOI: 10.5897/AJAR12.1687
ISSN 1991-637X ©2013 Academic Journals
http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Effect of soybean varieties on nutritional indices of beet armyworm *Spodoptera exigua* (Lepidoptera: Noctuidae)

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Accepted 29 April, 2013

The effects of three soybean varieties (Williams, BP and L17) on nutritional indices of *Spodoptera exigua* (Lepidoptera: Noctuidae) were determined at 25 ± 1°C, 65 ± 5% RH and a photoperiod of 16:8 (L:D) h. Nutritional indices of overall third to sixth larval instars indicated that, Williams and L17 varieties of soybean are more nutritionally rich food and even small amount of this food could successfully support maximum relative growth rate (*RGR*) as evidenced by high value of efficiency of conversion of ingested food (*ECI*), efficiency of conversion of digested food (*ECD*) and approximate digestibility (*AD*) among the soybean varieties. The lowest values of these parameters were found on BP variety. The larvae reared on Williams variety, had the highest value of larval, pre-pupal, pupal and adult weights. The results indicate that, Williams and L17 variety was the most nutritive and as a susceptible varieties among soybean varieties, in due to the highest value of *RGR*, *ECI*, *ECD*, *AD,* pre-pupal, pupal, and adult weights, in conversely, BP variety were recorded as partially resistant and the least nutritive for *S. exigua*, this is due to the fact that the least value of *RGR* and Feces produced (*FP*) were recorded.

Key words: Nutritional indices, *Spodoptera exigua*, food consumption, resistance, biomass.

INTRODUCTION

The beet armyworm, *Spodoptera exigua* (Lepidoptera: Noctuidae), is an economically important pest of crops worldwide, that attacks plants from over 20 families including trans-continental agricultural cotton, corn and citrus crops (Zhang et al., 2011). The beet armyworm, *S. exigua* Hubner (Lepidoptera: Noctuidae), is a widespread and polyphagous pest, which attacks more than 90 plant species in at least 18 families including Liliaceae, Fabaceae, Solanaceae, Malvaceae, Chenopodiaceae, Apiaceae, Asteraceae and Amaranthaceae, that causes severe economic damage to main crops such as sugar beet, soybean, cabbage, cauliflower, Brussels sprouts, tomato, maize and cotton (Mehrkhou et al., 2012 a,b). Although it can be controlled by insecticide application, the use of pesticide sprays on crop plants is considered undesirable by consumers. Consequently, there is a need for the development of alternative insect pest control strategies, as well as improvements in the effectiveness of currently employed pest control strategies (Chougule et al., 2008). A possible strategy to control insect pests is to produce crops with elevated levels of endogenous resistance. The outbreak of this pest has been attributed to the development of insecticide resistance (Brewer et al., 1990). Because of the economic importance of *S. exigua* as a pest species, there has been considerable research on various aspects of its developmental biology, as well as some basic measures of fitness on various field hosts and artificial diets. The destructive effects of the pest on the production and handling of many crops make this insect an important target for study. Therefore, the present research has increasingly been carried out to identify alternative measures to chemical control.

The chemical composition of host plants significantly affects survival, growth, and reproduction of

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phytophagous insects (Bernays and Chapman, 1994). Food consumption and utilization link plant attributes with insect performance (Slansky, 1990). For polyphagous insects, the availability of different host plants plays an important role in triggering population outbreaks (Singh and Parihar, 1988). Growth, development, and reproduction of insects are strongly dependent on the quality and quantity of food consumed (Scriber and Slansky, 1981). Of the tools of pest management, host plant resistance is important in terms of being both economically and environmentally acceptable. Therefore, as a method of controlling pest insects, host plant resistance is not only favorable to the environment, but also reduces expenses for growers (Li et al., 2004).

The factors determining nutrient availability for growth and maintenance over a given period of development are the amount and type of food consumed and the efficiency with which is utilized (Barton and Raubenheimer, 2003). Previously Mehrkhou et al. (2012a, b) examined development and fecundity of *S. exigua* on different soybean cultivars. The data obtained in that study allowed for an estimate of two of the major factors determining the susceptibility of soybean varieties, the developmental time and fecundity of *S. exigua*. In this research, this work was extended, and the effects of different soybean varieties on nutritional indices of *S. exigua* were elucidated as other factors determining the susceptibility of the examined varieties to this pest. By combining the data from the earlier study and the findings of the current research, a comprehensive scheme for an integrated pest management program for *S. exigua* on soybean could be designed.

The nutritional indices of the Cotton Bollworm, *Helicoverpa armigera*, on 13 Soybean varieties has been studied by Naseri et al. (2010). In spite of the economic importance of *S. exigua*, no information exists on the nutritional indices of this pest on different soybean varieties, although some related studies have been conducted on the effects of host plants on fecundity and life history of *S. exigua* (Azidah and Sofian-Azirun, 2006a, b). Therefore, the present study provides new information on the nutritional indices of *S. exigua* on different soybean varieties.

MATERIALS AND METHODS

Host plants

Seeds of three soybean cultivars including Williams, L17 and BP were obtained from the Plant and Seed Modification Research Institute (Karaj, Iran). Selection of these cultivars was based on their importance as most commercial cultivated cultivars in different regions of Iran. Soybean plants were grown in plastic pots (20 cm diameter × 20 cm height) containing a mixture of soil, peat moss and vermiculite (in a ratio of 1: 1: 1) in a greenhouse.

Insect culture

Beet armyworm larvae were originally collected from sugar beet field in Salmas (38° 11' N, 44° 46' E), west Azerbaijan province (west northern of Iran) in August 2011. The larvae were divided into three groups and reared for one generation on each soybean cultivars before using in the experiments. The experiments were held in growth chambers at temperature of 25 ± 1°C, 60 ± 5% R. H. and a photoperiod of 16: 8 (L:D) h.

Experiments

From F1 population, the neonate larvae were taken out and were reared till they reached the third instar. From this culture, third instar larvae were collected and divided into 5 replicates (10 larvae in each replicate). Thereafter the fifth and sixth instar larvae were reared individually on nine soybean varieties to avoid cannibalism. Larval feeding on the three different soybean varieties was tested by placing third instar larvae on a weighed leaf, which was placed inside a plastic Petri dish (diameter 16.5 cm, depth 7.5 cm) with a hole covered by fine mesh net for ventilation, containing the fresh leaves of each examined plant, and the ends of the petioles wrapped in moistened cotton to prevent desiccation. After 24 h., feces were removed from the uneaten leaves and weighed again. Petri dishes were cleaned, and new weighed leaves were supplied. This process was continued each day for each replicate until feeding ceased in the pre-pupal stage. Petri dishes were held at temperature of 25±1°C, 60±5% R. H. and a photoperiod of 16:8 (L:D) h. Daily food consumption per larva was estimated by subtracting weight of remaining leaf tissue from weight of leaf provided and correcting for evaporation. All pupae were weighed and their sex determined. Nutritional indices were measured on the dry weight basis. The pre-pupa, pupa, and adults from the larvae reared on each variety were weighed as well. The weight of feces produced by the larvae fed on each soybean variety was recorded daily. To find the dry weights of the leaves, feces, and larval to adult stages, extra specimens (20 specimens for each soybean variety) were weighed, oven-dried (48 h at 60°C), and then re-weighed to establish a percentage of their dry weight. Nutritional indices were calculated on the basis of dry weight, as suggested by Waldbauer (1968) and Huang and Ho (1998) to calculate relative consumption rate (*RCR*), relative growth rate (*RGR*), approximate digestibility (*AD*), efficiency of conversion of ingested food (*ECI*) and efficiency of conversion of digested food (*ECD*):

$$RCR = I/B \times T \quad (1)$$

$$RGR = (F_W - I_W)/(I_W \times T) \quad (2)$$

$$ECI\ (\%) = B/I \times 100 \quad (3)$$

$$ECD\ (\%) = B/(I-F) \times 100 \quad (4)$$

$$AD\ (\%) = (I-F)/I \times 100 \quad (5)$$

Where, I is the dry weight of food consumed, F is the dry weight of feces produced, I_w is the initial weight, F_w is the final weight, T is the duration of feeding period (days) and B is the insect dry weight gain.

After the pupa developed to adults, the number of eggs that was laid by per female during life time was also, determined.

Data analysis

Data were checked for normality prior to analysis. Statistical processing of results was carried out by standard methods using the statistical software SPSS ver.16 (SPSS, 2007). If significant differences were detected, means were compared suing Duncan’s test at α = 0.05.

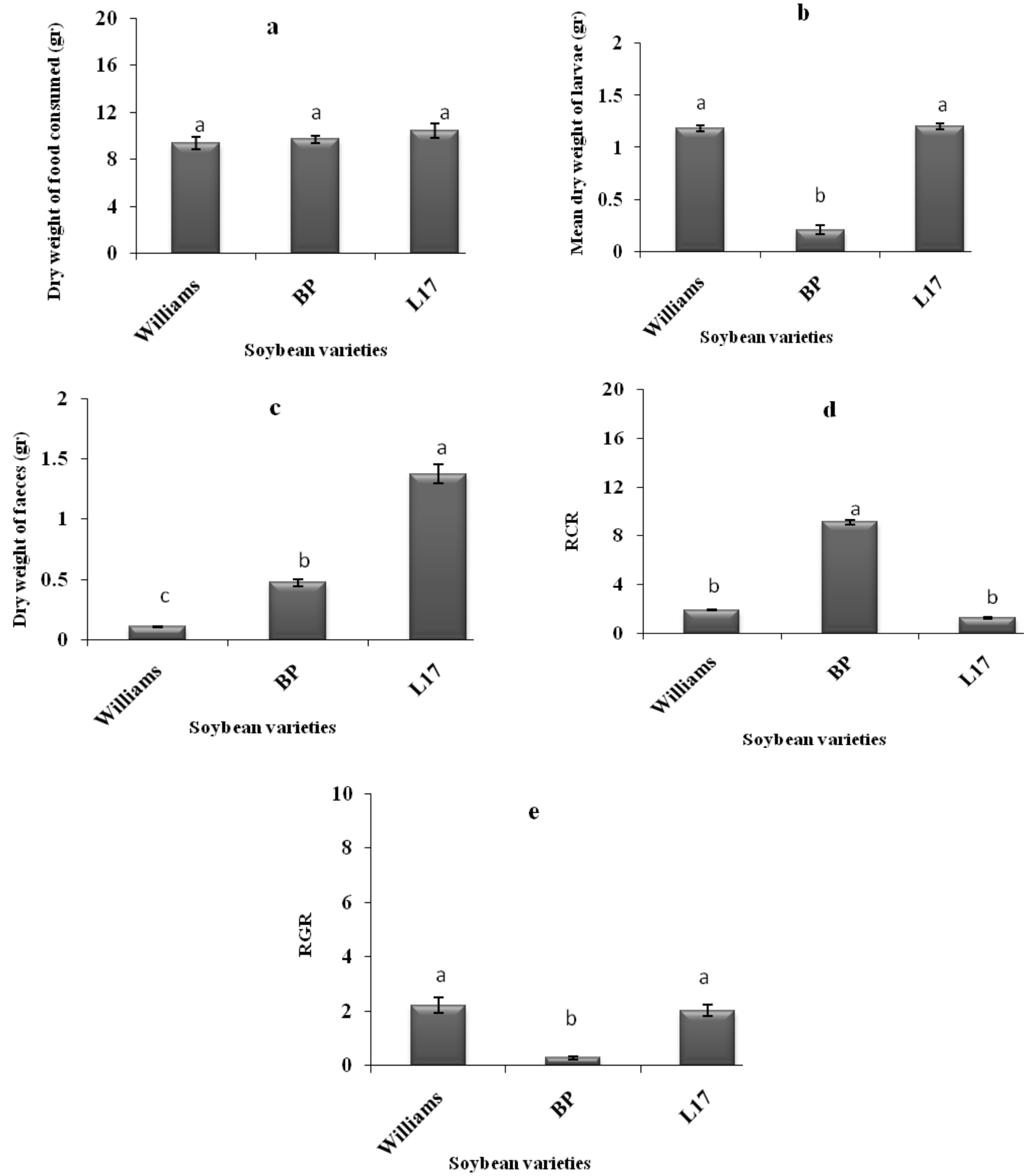

Figure 1. Food consumption (a), larval weight (b), feces produced (c), relative consumption rate (d) and relative growth rate (e) of whole larval instars of *S. exigua* on different soybean varieties.

RESULTS

The results of the nutritional indices of whole larval instars of *S. exigua* are provided in Figures 1 and 2. Nutritional indices including food consumed (F=0.81; df=52; P>0.05), larval weight (F=19.23; df=52; P<0.01), dry weight of feces produced (F=101.34; df= 52; P<0.01), *RCR* (F=19.76; df=52; P<0.01), *RGR* (F=22.28; df=52; P<0.01), *ECI* (F=17.65; df=52; P<0.01), *ECD* (F=15.63; df=52; P<0.01) and *AD* (F=59.54; df =52; P<0.01) for whole larval instar were significantly different on soybean varieties.

The highest larval weight gain (larval biomass) were recorded from Williams (1.18±0.03 g) and L17 (1.20±0.03 g) varieties, while the lowest of this parameters was obtained on BP (0.21±0.05 g) variety. The highest and

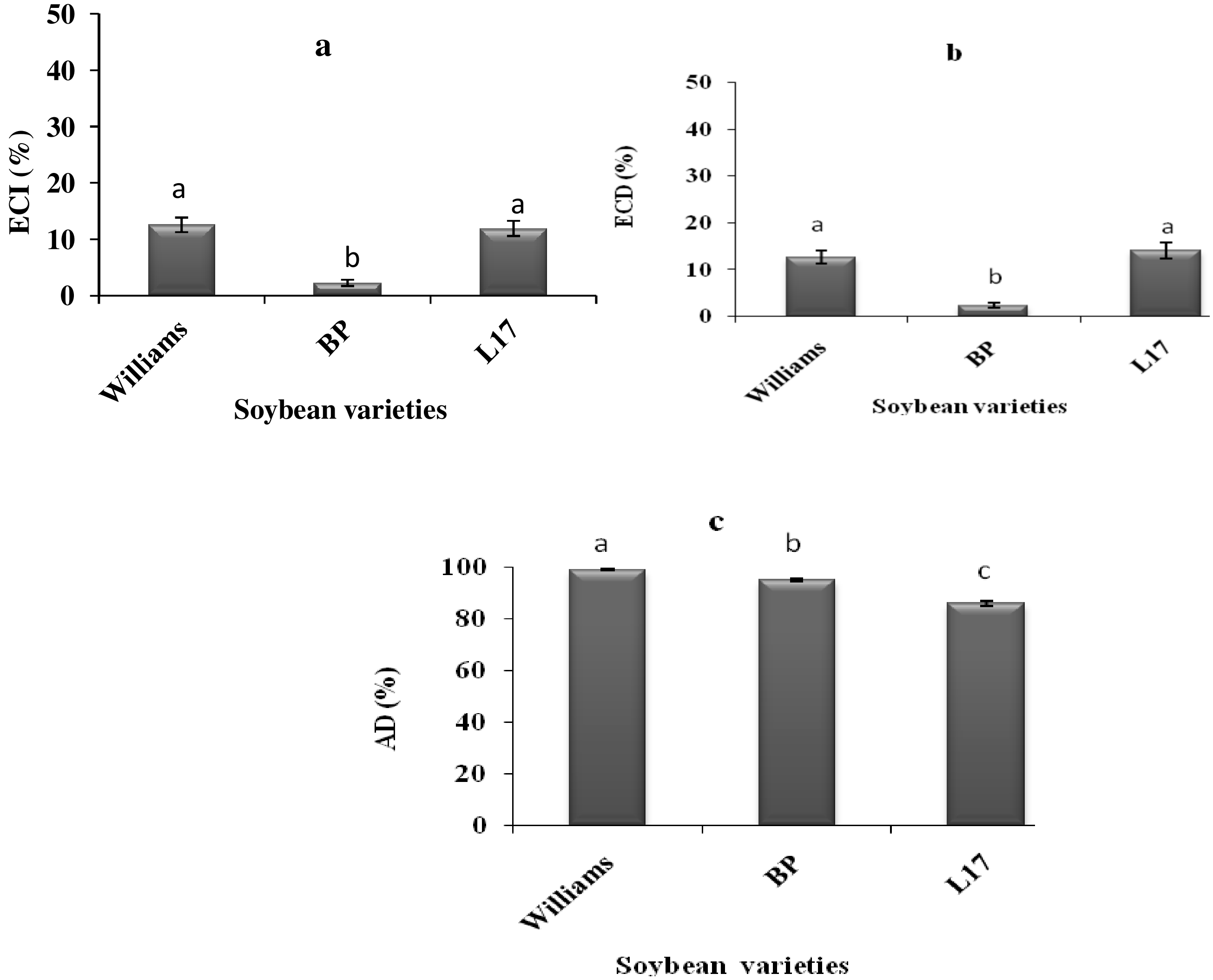

Figure 2. Efficiency of conversion of ingested food (a), efficiency of conversion of digested food (b) and approximate digestibility (c) of whole larval instars of *Spodoptera exigua* on different soybean varieties.

lowest value of feces produced by larvae of *S. exigua* were recorded on L17 (1.38 ± 0.08 g) and Williams variety (0.11 ± 0.00 g), respectively. The highest rate of relative growth rate (*RGR*), efficiency of conversion of ingested food (*ECI)* and efficiency of conversion of digested food (*ECD)* were observed on both of soybean varieties (Williams and L17). The relative growth rate was varied from (0.30 ± 0.06 mg/mg/day) to (2.21 ± 0.28 mg/mg/day) on BP and Williams variety, respectively. In conversely of relative growth rate, the relative consumption rate was the highest rate on BP (9.145 ± 0.20 mg/mg/day) and it was the lowest rate on L17 (1.257 ± 0.05 mg/mg/day). Two important parameters of nutritional indices including efficiency of conversion of ingested (*ECI*) and the efficiency of conversion of ingested food (*ECD*) by larval of *S. exigua*, which is reared on Williams and L17 variety were the higher rate than BP variety. The efficiency of conversion of digested food was varied from (2.24 ± 0.541%) to (12.55 ± 1.31%) on BP and Williams variety, respectively. Similarly, the lowest rate of efficiency of conversion of ingested food was observed on BP variety (2.37 ± 0.58%), while the highest of *ECD* was recorded on L17 (14.16 ± 1.73%).

The highest value of *AD* was recorded on Williams variety (98.79 ± 0.09%), which is the lowest rate on L17 (85.79 ± 1.06%) variety. Our finding regarding to pre pupa, pupal and adult weight of *S. exigua* indicated that, there is significant difference on pre pupa ($F=5.70$; $df= 49$; $P<0.01$), pupal ($F= 6.16$; $df= 63$; $P<0.01$) and adult ($F= 3.43$; $df= 53$; $P<0.01$) weight of beet armyworm on different soybean varieties. The heaviest and lightest of Pre-pupa and pupa of larvae reared on Williams and BP, respectively and the L17 was moderate (Table 1). The adults who reared on Williams and L17 were heavier than

Table 1. The mean (±SE) body weights of pre-pupa, pupa and adult stages of *S. exigua* on different soybean varieties in 2011.

Soybean varieties	Pre-pupa (g)	Pupa (g)	Adult (g)
Williams	0.074 ± 0.003[a]	0.060 ± 0.003[a]	0.031 ± .002[a]
BP	0.057 ± 0.001[b]	0.051 ± 0.001 [b]	0.026 ± 0.001[b]
L17	0.068 ± 0.003 [ab]	0.055 ± 0.001[ab]	0.031 ± 0.001[a]

The means followed by different letters in the same columns are significantly different (P < 0.01, Tukey's test).

BP adults.

DISCUSSION

Approximate digestibility (*AD*), efficiency of conversion of digested food (*ECD*) and efficiency of conversion of ingested food (*ECI*) are the most important parameters of nutritional indices (Reese, 1978). *AD*, ECD and ECI measure the assimilation of food, the efficiency with which assimilated food is converted into insect biomass and the overall conversion of ingested food into biomass, respectively (Waldbauer, 1968), which insure the growth and development (Nathan et al., 2005). Significant differences were found within the nutritional indices, mainly *ECI*, *ECD* and *AD* values of *S. exigua* reared on different soybean varieties, suggesting that the varieties have different nutritional value. The highest value of *ECI* and *ECD* of whole larval instars on Williams and L17 varieties of soybean, suggests that, they were more efficient at the conversion of ingested food to biomass and weight gained by larvae (Nathan et al., 2005). As can be seen (Figure 2a, b). The larvae reared on BP variety had the lowest value of *ECD*, which indicate that, these larvae were apparently not as efficient in turning digested food into biomass. Additionally, Williams and L17 varieties of soybean is more nutritionally rich food and even small amount of this food could successfully support maximum insect growth as evidenced by high *ECI*, *ECD* and *AD* among the soybean varieties used in the present experiment. The low consumption rates observed on Williams are, therefore, not likely to be the result of an aversion to it as a host plant.

A more plausible explanation is that Williams variety is of higher nutritional quality for *S. exigua* than the other soybean varieties tested. All nutritional parameters on BP were far below than the Williams. All these indices were maximum among the test-food showing the nutritional superiority of Williams, this is due to the fact that, it is most preferred by the test insect. In the comparison of nutritional indices of *S. exigua* between three varieties showed that, the Willliams variety was more suitable variety than others. It was due to the high rate of approximate digestibility and the lowest rate of feces produced and food consumed. The lowest rate of *AD* on L17 variety shows that, the larval of beet army-worm produced the most rates of feces in comparison of other soybean varieties, which is citied by Waldbauer (1968). The effect of 13 soybean varieties on nutritional indices of *H. armigera* has been studied by Naseri et al. (2010). Their results showed that the larvae which is reared on BP variety, has the highest rate of *AD*, *ECD*, *ECI*, *RGR* rather than to Williams and L17, their results is against our finding. It might be due to the type of regimes, which the species feed on. In the other word the *S. exigua* feed on the leaves of soybean, whereas the *H. armigera* feed on the beans of soybean. Greenberg et al. (2001) examined feeding and life history of *S. exigua* on different host plants. They found that, mean total leaf weight consumed by larvae was highest in cabbage (2.7 g) and lowest in pigweed (1.6 g). East et al. (1994) studied larval consumption rates among larvae of *S. exigua* on cabbage. Mean larval consumption was 0.039 g of cabbage daily, or 1.53 g per larva for the entire larval feeding period at 25 ± 1℃. We found higher consumption levels on BP (9.40 ± 0.83 g) variety per larva.

This variation could be due to the existence substances in host plants that can deter beet armyworm feeding (Mitchell and Heath, 1985). Larvae feeding on Williams produced pupae that averaged 0.060 ± 0.003 mg, compared with other soybean varieties. Similar results were reported by Azidah and Sofian-Azirun (2006b), who studied fecundity of *S. exigua* on different host plants. Among four host plants (cabbage, shallot, long bean and lady's finger) the highest and lowest pupal weights were obtained on shallot (56.70 mg) and lady's finger (38.60 mg), respectively. Greenberg et al. (2001) reportd that, the mean pupal weight was highest on pigweed, followed by cabbage, cotton, and pepper, and lowest on sunflower. Idris and Emelia (2001) found that the fecundity of adult emerged fed on onion and okra were higher than in other treatments. They found that the highest and lowest numbers of eggs produced per female were 199.00 ± 3.06 on onion and 173.33 ± 3.53 on chilli, respectively. Shafqat et al. (2010) examined effect of host plants (cauliflower, wheat and pea) on life-history traits of *S. exigua*, who reported that, the higher pupal weight on cauliflower (88.7 mg) suggest that it provides better food quality to *S. exigua* compared with peas (54.9 mg) and wheat (30.8 mg).

The soybean varieties effect on adult weights too, as can be seen in Table 1, the larvae reared on Williams variety, had the highest value of larval weight, pupal weight and adult weight, it means that, total stages including: larvae, pre-pupa, pupa and adult were affected by soybean varieties, so, the quality of larval food may affect the other stages. Variation in the nutritive values of the diet from different plants and the extent to which they are consumed and utilized by *S. exigua,* considered as the determining factors of its growth and establishment. The present study shows significant differences in the capacity of *S. exigua* reared on different soybean varieties. Such observations will help in selection of host-plant-resistance of test insect as well as for constructing mathematical model, which will be helpful in developing strategy for sustainable management against this pest. Also the determination of consumption and utilization of host plants by insect herbivores is a commonly used tool in studies of plant insect interactions (Scriber and Slansky, 1981). Study of the effect of food on the biology of insects is of particular importance in understanding host suitability of plant infesting species and evaluating the magnitude of injury to the crops attacked by them. This may help, accordingly, in designing more economic control strategies (Greenberg et al., 2001).

ACKNOWLEDGMENTS

We thank to the Department of Agricultural Entomology, Tarbiat Modares University for financial supporting this research. This research was partly supported by a grant from the Centre of Excellence for Integrated Pests and Diseases Management of Oil Crops of Iran, which is greatly appreciated.

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