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Influences of Different Host Plants on Biological and Food Utilization of the Cotton Leafworm, *Spodoptera littoralis*

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GRAPHICAL ABSTRACT

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ABSTRACT

The effects of four host plants, broad bean, cabbage, clover and tomato as foods for *Spodoptera littoralis* (Lepidoptera: Noctuidae), on certain biological aspects of the insect were studied under laboratory conditions (25 ± 1°C and ≈70% R.H). The results and statistical analysis showed that all of the biological parameters included in the study were affected by the host plants whereas the shortest larval duration (13.2 ± 0.577 days) was recorded for larvae fed on cabbage and the longer (23.3 ± 0.76 days) resulted when larvae fed with tomato. The pupation percentages on tomato leaves were lowest (58.2 ± 1.79 %) and highest pupation was (86.7 ± 1.36 %) when larvae fed on cabbage leaves. Moreover, adult emergence percentages were (80 ± 0.38 %) in tomato and (98 ± 1.36 %) on cabbage. The numbers of eggs oviposited by female S. *littoralis* were highest on cabbage, followed by those on the broad bean, clover, and lowest on tomato. Based on the nutritional values of testing host plants proved to be effective in reduced development and reproductive capacity of *S. littoralis*. Also, results proved that cabbage leaves most favorable host for *S. littoralis* larvae followed by broad bean leaves. While tomato and clover leaves were the relative unsuitable due to the differences in the leaf nutritional quality as mentioned during phytochemical analysis and the high level of amino acid in the hemolymph of larvae fed on cabbage and broad bean leaves.

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1- INTRODUCTION

The cotton leafworm *Spodoptera littoralis* (Boisd.) (Lepidoptera: Noctuidae), it is still considered as one of the most destructive insect pests not only in Egypt but also in other countries. This insect, a serious and voracious pest, damaging to a wide variety of host plants cover over 112 species, approximately belonging to 44 different families of plant crops. *S. littoralis* larvae prefer to feed on young leaves, young shoots, stalks, bolls, buds, and fruits. In addition to its direct damage, too, reduce the photosynthetic area and reduce the marketability of vegetables and ornamentals[1]. Over the past 40 years, the intensive use of broad-spectrum insecticides against the *S. littoralis* had

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led to the development of resistance to many of them. Previous researchers demonstrated that plants were considered one of the richest sources which could be used as pest control agents. Therefore, different host plants could play an important role in population increase and outbreaks of insect pests. Most insects have qualitatively similar nutritional requirements because the basic chemical composition of their tissues and their metabolic processes are generally similar most of these requirements are normally met by the diet. Therefore, the diet in terms of quality and the quantity of food consumed may affect insect development, survivorship, reproduction, and life span parameters[2, 3]. So, when feed on Low-quality plants may reduce insect survival, size or weight, their longevity, and reproduction viabilities or indirectly increase their exposure to the natural enemies as a result of prolonged developmental time. Field observations refer that the susceptibility of the host plants to infestation varies according to their suitability for the pest[4]. Therefore, the study of the effects of host plants on the biology of insects is important in understanding the host suitability of plant-infesting insect species.

Thus, the objectives of this study were to investigate the influence of the rearing of *S. littoralis* larvae on various host plants on the development, reproduction capacity, nutritional indices and to study the changes in free amino acids composition of hemolymph larvae by the leaf composition of the different host plants used.

2. EXPERIMENTAL

2.1. Stock colony

The stock culture of the Egyptian cotton leafworm, *S. littoralis* was maintained for several years without exposure to any pesticides in the laboratory at room condition was kept at a temperature of 25 ± 1 °C, ≈70% RH, with a 16: 8 L: D photoperiod. The larvae were fed on castor oil leaves (*Ricinus communis* L.), fresh, clean leaves were supplied daily. Newly emerged adults were transferred into plastic jars for mating and egg-laying. Adults were fed on a 10% sucrose solution impregnated onto cotton wool. Egg masses deposited by females of the stock culture were collected daily, and the hatched larvae were transferred to the host plant.

2.2. Host plants

Four host plants were used in this study, including broad bean (*Vicia faba*), cabbage (*Brassica oleracea*), clover (*Trifolium alexandrium*), and tomato (*Solanum* l*ycopersicum*). The selection of these plants was based on their importance as crops in Egypt and are primary host plants of *S. littoralis*. Furthermore, *S. littoralis* causes considerable damage to those host plants. All plant materials used in this experiment were collected from plants grown under field conditions without using any pesticides.

2.3. Experimental Procedures

This experiment was planned and carried out to assess the effect of host plants on the biology of *S. littoralis* the insect was reared on the host plants mentioned above. One hundred newly hatched larvae were set for each host-plant, and four replicated were set for each used host plant. Survival pupae were counted, sexed, and weighed at 24 hr-old, and kept until adult emerged. Larval duration, pupal duration, weight, and survivorship were determined. Freshly emerged moths of each host plant were paired. Each pair (male and one female) was placed in a glass jar and fed on 10% fresh sucrose solution. A folded sheet paper was placed in the jar to provide suitable sites for oviposition. The effects of various tested host plants on fecundity (total number of eggs/female), fertility (hatchability percentages of eggs), and the longevity of adults of both sexes were determined. The mating cups were checked daily, and egg masses were removed by female death. The total number of eggs/female for each mating and hatched eggs percentages were evaluated.

2.4. Food consumption and utilization

Newly hatched sixth instar larvae that had been reared on mentioned host plants kept in containers with the hole covered by a mesh net for ventilation were used in this study. Leaves and larvae were weighed and placed inside containers. The weights of the larvae were recorded daily before and after feeding until they finished feeding and reached the pre-pupal stage. The initial fresh food, the food, and feces remaining at the end of each experiment were weighed daily. Containers were cleaned, and new weighed leaves were supplied. Food utilization rates were then calculated according to[5] CI (Consumption index), AD (Approximate digestibility), ECI (Efficiency of conversion of ingested food), ECD (Efficiency of conversion of digested food), RCR (Relative consumption rate), and RGR (Relative growth rate):

$$CI = \frac{E}{A}$$

$$RCR = \frac{E}{A\ x\ T}$$

$$RGR = \frac{P}{A\ x\ T}$$

$$AD\ (\%) = \left\{\frac{E-F}{E}\right\}\ x\ 100$$

$$ECI\ (\%) = \left\{\frac{P}{E}\right\}\ x\ 100$$

$$ECD\ (\%) = \left\{\frac{P}{E-F}\right\}\ x\ 100$$

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 (day), F-the dry weight of feces produced (mg).

2.5. Phytochemical composition of the different host plants

Plant leaves of broad bean; cabbage, clover, and tomato were dried in the oven and prepared for spectrophotometer analysis. Total carbohydrates were measured according to [6, 7]. Total protein was determined according to the method of [8]. Total nitrogen was determined according to [9]. Phenolic compounds were extracted from dried leaves according to the method of [10].

2.6. Amino acid composition of *S. littoralis* larvae

The hemolymph of the last larval instars fed on a broad bean, cabbage, clover, and tomato leaves, was collected (after cutting a prologue, on ice) in a propylene microcentrifuge tube containing few crystals of phenylthiourea to prevent melanization. The hemolymph was centrifuged at 3000 r.p.m. for 5 min at 4˚C to remove hemocytes. All the hemolymph samples were kept on -20˚C until amino acid analysis was carried out. The samples were hydrolyzed in sealed, evacuated ampoules in an oven at 110˚C for 16 h. The extraction and analysis were performed according to the methods described by [11].

2.7. Statistical analysis

The data mentioned above were subjected to analysis of variance (ANOVA) using SPSS 12.0 software (Statistical Package for Social Sciences, USA). Mean values were compared using [12].

3. RESULTS

3.1. Effect of four host plants on the food utilization and nutrition indicates of *S. littoralis*

The results presented in **Table (1)** showed that the different host plants had significant effects on nutritional indices of *S. littoralis*. All data were recorded at the end of the larval instar. The larvae reared on tomato showed the highest values of ECD and ECI compared with that reared on other host plants. The lowest values of ECD were on cabbage. The highest values of AD and CI were observed on cabbage. However, the lowest values of AD and CI were on broad bean and clover, respectively. The highest values of RCR and RGR were observed on cabbage and broad bean, respectively. The highest value of food consumption and feces produced was found on cabbage, and the highest value of larval dry weight gain was clover. The least amount of feces was produced on tomato.

Table 1. Nutritional indices of during the larval stage of *S. littoralis* on four host plants

Parameters	Tomato	Broad bean	Clover	Cabbage
RCR (mg/mg/day)	0.338^{a} ± 0.066	0.730^{b} ± 0.064	0.714^{b} ± 0.091	1.680^{c} ± 0.185
ECD (%)	22.175^{c} ± 1.735	20.396^{c} ± 1.581	15.295^{b} ± 0.86	4.389^{a} ± 0.493
CI	7.433^{a} ± 0.919	9.152^{a} ± 1.394	9.900^{a} ± 0.681	34.960^{b} ± 5.43
ECI (%)	19.093^{b} ± 0.641	15.475^{b} ± 0.53	12.833^{b} ± 1.043	3.820^{a} ± 0.033
RGR (mg/mg/day)	0.069^{a} ± 0.007	0.148^{c} ± 0.018	0.126^{b} ± 0.003	0.093^{a} ± 0.003
AD (%)	86.102^{b} ± 1.863	75.872^{a} ± 6.275	83.908^{b} ± 1.810	87.046^{b} ± 1.141
E (mg)	4.677^{a} ± 0.493	4.588^{a} ± 0.629	6.935^{a} ± 0.620	24.711^{b} ± 3.414
F (mg)	0.650^{a} ± 0.541	1.107^{b} ± 0.117	1.116^{b} ± 1.117	3.201^{b} ± 0.048
P (mg)	0.893^{a} ± 0.096	0.710^{b} ± 0.04	0.890^{a} ± 0.087	0.944^{a} ± 0.065

P = dry weight gain, E = dry weight of food ingested, F = the dry weight of feces produced. Means in a row followed by the same letter are not significantly different at P<0.05

No significant differences were observed on the dry weight gain among the four host plants. Data indicate that all the tested host plants significantly reduced the weight of consuming leaves larva, and there is a gradual decrease in consumption tomato gave better results followed by clover, broad bean, and cabbage.

3.2. Influence of host plant on the development of the immature stages

Tables (2, 3, and 4) compares the main biological aspects of *S. littoralis* larvae reared on tomato, clover, broad bean, and cabbage leaves. It is observed that the larvae duration, pupal duration, and the life span were generally different from one host plant to another one. Overall larval development was significantly affected by host plants, was long on tomato (23.3±0.76 d), followed by clover (18.6±1.029 d), broad bean (16.5 ±0.886 d), and shortest on cabbage (13.2±0.577 d), (**Table 2**). Since tomato was the most effective among the tested one, it was used as a standard in calculating the percent reduction for males and females. The results indicated that the longevity of moths in general; females lived 1-1.5 days longer than males. The results proved that the duration of the developmental period could be influenced by the suitability of the host plant.

Data in **Table (3)** indicated that all host plants decreased significantly (P<0.05) and highly significantly (P<0.01) the mean pupal weight, tomato shows a higher effect followed by broad bean and clover at the same time, the cabbage lowest effect the same trend was also observed for pupation and adult emergence percent. Where the highest adult emergence percentages from pupae were (98±1.36 %) on cabbage, followed by broad bean and clover (96±2.59 and 95±1.24 %) respectively, while the tomato lowest effect (80±0.38 %). Data indicate that pupation percentage and adult emergence percentages, upon cabbage were non-significantly different from the remaining host plants, but were significantly different from tomato. Moreover, the survival larvae rate varied on the four host plants the highest rate was observed on larvae were fed with the cabbage (77.9±1.2 %), followed by that on broad bean (74.4±1.95 %) clover (67.3±1.21 %), as compared to those reared on tomato leaves (57.1±1.4 %). It also has been observed that *S. littoralis* larvae up to their third and fifth-instar usually remain in their host plant, but sixth-instar larvae leave the host plant because stope it has fed (pre-pupal stage). Also, in most cases, the female pupae were generally heavier than male pupae; these usually mean that weighs gain of larvae was reduced. The results of **Table (4)** show that these host plants reduced all the progeny of *S. littoralis*.

Table 2. Effect of four host plants on development periods of *S. littoralis*

Host plants	Larval duration (days) ± SE	Pupal duration (days) ± SE	Pre-pupa duration (days) ± SE	Longevity (days) ± SE				Developmental period (days) ± SE	
				males	Reduction (%)	females	Reduction (%)	males	females
Tomato	23.3^{b} ± 0.76	10.8^{a}±0.85	1 ± 0	6.8^{a} ± 0.5	0.0 ± 0.0	7.7^{a} ± 1.81	0.0 ± 0.0	41.9^{b}± 0.91	42.8^{b} ± 1.91
Clover	18.6^{a} ±1.029	10.0^{a} ± 2.7	1 ± 0	6.7^{a} ± 0.3	1.47^{a} ± 0.13	7.5^{a} ± 0.22	2.60^{a}±1.47	36.3^{b}±2.4	37.1^{b} ± 1.85
Broad bean	16.5^{a} ±0.886	9.7^{a} ± 0.06	1 ± 0	6.2^{a} ± 0.6	8.82^{a} ±1.35	6.9^{a} ± 0.57	10.39^{b}±0.15	33.4^{a}±3.7	34.1^{a} ± 1,83
Cabbage	13.2^{a} ±0.577	9.1^{a} ± 0.27	1 ± 0	6.0^{a} ± 0.3	11.76^{a} ± 1.68	6.3^{a} ± 0.65	18.18^{b}±0.3	29.3^{a}±0.35	29.6^{a} ± 3.78

Means followed by the same letter in the same column are not significantly different at P<0.05. Tomato was the most effective among the tested one, it was used as a standard in calculating the percent reduction for males and females.

Table 3. Effect of four host plants on some of biological aspects of *S. littoralis*

Host plants	Mean larval weight (g) ± SE	Survival larvae rate (%) ± SE	Mean pupal weight (g) ± SE	Pupation (%) ± SE	Adult emergence (%) ± SE
Tomato	0.312^{a} ± 0.02	57.1^{a} ± 1.4	0.204^{a} ± 0.32	58.2^{a} ± 1.79	80^{a} ± 0.38
Clover	0.340^{b} ± 0.23	67.3^{b} ± 1.21	0.221^{b} ± 0.31	62.4^{a} ± 1.91	95^{b} ± 1.24
Broad bean	0.348^{b} ± 0.01	74.4^{b} ± 1.95	0.248^{c} ± 0.24	74.0^{b} ± 0.54	96^{b} ± 2.59
Cabbage	0.364^{c} ± 0.26	77.9^{b} ± 1.2	0.276^{c} ± 0.27	86.7^{b} ± 1.36	98^{b} ± 1.36

Means followed by the same letter in the same column are not significantly different at P<0.05.

Table 4. Mortality percentages of the development stages exposed of *S. littoralis* to four host plants

Host plants	Larval mortality (%)	Pupal mortality (%)	Adult mortality (%)	Accumulative mortality
Tomato	20.1^{b} ± 0.98	25.2^{b} ± 0.45	29.3^{b} ± 0.62	74.6^{c} ± 0.16
Clover	16.2^{ab} ± 0.28	19.1^{a} ± 0.72	24.3^{b} ± 1.96	59.6^{c} ± 6.3
Broad bean	12.1^{a} ± 1.17	15.3^{a} ± 0.63	18.0^{a} ± 1.4	45.4^{b} ± 0.91
Cabbage	10.2^{a} ± 0.98	13.5^{a} ± 1.15	12.2^{a} ± 1.91	35.9^{a} ± 0.96

Means followed by the same letter in the same column are not significantly different according to at P<0.05.

3.3. Influence of host-plant on reproduction of the adult stage

Concerning the latent effects, the data in Table (5) indicated that all host plants decreased significantly (P<0.05) and highly significantly (P<0.01) the mean fecundity (eggs/female) and fertility (egg hatching) and increased the sterility percent. A gradual decrease in reproductive parameters and percent sterility with increasing by tomato (27.34 ± 2.03 %) gave better results followed by broad bean and clover (13.33 ± 0.57 and 3.28 ± 0.35 %) respectively. As compared to those reared on cabbage leaves were (387 ± 0.26 fecundity and 88.5 ± 0.41 % fertility). Whereas the cabbage was the most effective among the tested one, it was used as a standard in calculating the percent sterility. On the other hand, *S. littoralis* females oviposited most on clover, least on tomato, and intermediate on broad bean and cabbage.

Table 5. Effect of four host plants on reproductive parameters and percent sterility of *S. littoralis*

Host plants	Reproductive parameters		Sterility (%) ± SE
	Fecundity (eggs/female) ± SE	Fertility (egg hatching %) ± SE	
Tomato	0.295^{a} ± 0.12	64.3^{a} ± 4.8	27.34^{c} ± 2.03
Clover	0.327^{b} ± 0.21	76.7^{a} ± 1.9	13.33^{b} ± 0.57
Broad bean	0.349^{c} ± 0.23	85.6^{b} ± 1.45	3.28^{a} ± 0.35
Cabbage	0.387^{d} ± 0.26	88.5^{b} ± 0.41	0.0 ± 0.0

Means followed by the same letter in the same column are not significantly different at P<0.05. Cabbage was the most effective among the tested one, it was used as a standard in calculating the percent sterility.

Table 6. The mean total carbohydrates, total proteins, nitrogen and phenolic concentrations of the four host plant leaves

Host plants	Total carbohydrates (g/100g) ± SE	Total proteins (g/100g) ± SE	Nitrogen (g/100g) ± SE	Phenolic (g/100g) ± SE
Tomato	23.742^{a} ± 0.26	10.194^{a} ± 0.42	1.887^{a} ± 0.22	4.631^{a} ± 0.72
Clover	25.021^{a} ± 1.91	12.131^{b} ± 1.92	2.565^{ab} ± 0.6	2.773^{b} ± 0.31
Broad bean	26.212^{a} ± 1.51	14.022^{b} ± 1.95	3.020^{b} ± 0.24	1.911^{c} ± 0.16
Cabbage	28.261^{a} ± 1.22	16.246^{b} ± 0.54	3.443^{b}± 0.28	1.600^{c} ± 0.11

Means followed by the same letter in the same column are not significantly different at P<0.05.

3.4. Phytochemical composition of the different host plants

Carbohydrates form a large part of the diet of many insects, although they are a common source of energy, not always essential, which are usually necessary for normal growth. Therefore, **Table (6)** showed that the chemical composition of the broad bean, cabbage, clover, and tomato leaves revealed a significant decrease (P<0.05) in the total carbohydrates in cabbage leaves and a highly significant (P<0.01) decrease in tomato leaves as compared to clover and broad bean leaves level were detected in tomato leaves. Also, the results in **Table (6)** revealed a high level of phenolic compounds in tomato leaves (4.631±0.72) as compared to clover leaves (2.773±0.31), broad bean leaves (1.911±0.16) and cabbage leaves (1.600±0.11). **Table (6)** revealed during this study that cabbage leaves were the best host for *S. littoralis* larvae, this might be due to the high levels of total carbohydrates, total protein and nitrogen and the low level of phenolic compounds recorded in cabbage leaves.

3.5. Amino acid compositions

The amino acid levels in the last instar larval hemolymph of *S. littoralis* fed on the broad bean, cabbage, clover, and tomato leaves were depicted in **Table (7)**. Results that the essential amino acids (arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, and valine) together with the non-essential amino acids (aspartic, glutamic, glycine, serine and tyrosine) showed changing their level of the host plant to other another. Where results revealed that β-amino isobutyric was the most predominant amino acids in cabbage leaves, broad bean leaves, clover leaves and tomato leaves followed by tyrosine in cabbage leaves and broad bean leaves only. On the other hand, the least amino acid levels were methionine in cabbage leaves and broad bean leaves, taurine in clover leaves whereas, cystathionine and phenylalanine in tomato leaves. Although alanine and ornithine were not detected in larvae, which fed on tomato leaves but detected in larvae fed on other tested host plant leaves. Hemolymph amino acid of larvae fed on cabbage and broad bean leaves was characterized by the presence of proline and cysteine and by the absence of cystathionine and taurine.

Table 7. Amino acid compositions of the hemolymph of *Spodoptera littoralis* larvae fed on four host plant leaves

Amino acid	Concentration µg / ml			
	Tomato leaves	Clover leaves	Broad bean leaves	Cabbage leaves
Arginine	6.60	5.60	90.00	91.51
Histidine	36.00	63.15	121.44	123.40
Isoleucine	12.26	18.09	40.98	42.66
Leucine	12.11	22.56	55.05	56.17
Lysine	----------	48.81	110.80	111.72
Methionine	4.71	5.27	10.17	12.29
Phenylalanine	2.47	5.73	24.66	25.75
Threonine	11.83	35.18	48.25	49.28
Valine	6.55	15.70	42.88	43.95
Alanine	--------	6.66	20.00	21.17
Aspartic acid	5.41	8.90	21.92	23.73
Cysteine	--------	--------	44.66	45.57
Glutamic acid	15.62	24.94	70.37	71.39
Proline	--------	--------	121.56	123.55
Glycine	16.47	20.88	57.13	58.00
Serine	18.85	24.43	180.81	181.74
Tyrosine	13.37	21.18	340.73	341.51
α-aminoadipic acid	12.42	20.11	181.54	182.70
β-amino isobutyric	61.36	181.33	344.99	346.00
γ-aminobutyric	2.99	47.82	45.03	46.22
Ornithine	--------	5.11	20.60	22.51
Cystathionine	1.11	11.55	---------	--------
Taurine	--------	4.14	---------	--------
Phosphoserine	8.41	20.33	28.87	30.54
Total pool	248.54	599.47	2022.44	2051.36

DISCUSSION

The study of nutritional indices leads to a good understanding of the physiological behavior of insects for their host plants, where it is well known that the degree of food utilization depends on the digestibility of food and the efficiency with which digested food is converted to biomass. The results presented in **Table (1)** proved that the efficiency of the conversion of ingested food on tests host plants vary considerably by *S. littoralis*. The current data show that *S. ittoralis* had similar relative growth rates on cabbage and board bean where the larvae were more efficiently converting cabbage and board bean tissues into their biomass than other plant tissues as shown by larvae fed on tomato and clover where having the lowest digestibility and the lowest relative consumption rate. The present results are in agreement with those obtained by several authors, for example,[4, 13, 3] studied nutritional indices of different lepidopteran pests on various host plants, and they mentioned that nutritional indices could play an important role in the evaluation of the host plants.

The results presented in **Tables (2, 3, 4 and 5)** show that larval food directly effects of oviposition, larval and pupal development and survival, pupal weight, and oviposition of emerged females when cabbage, broad bean, clover, and tomato were offered as the food plants for their larvae, The present results are in parallel with that of [14], where they reported that, when the quantity of food ingested is decreased, the duration of development is extended and insect becomes smaller and lighter. Another reason may be related to increased instar duration when an increased amount of consumed food must be used to maintain metabolism. Also,[3], they reported that larvae of *H. armigera* and *S. exigua* fed on chickpea, canola, and eggplant had the highest AD while their ECD values were the lowest these effects might be due to physiological disturbance in hormonal systems of adults which leads to an increase in the rate of sterility. Also, revealed this study that cabbage and broad bean leaves were the best host for *S. littoralis* larvae, this might be due to the high levels of total carbohydrates, total protein and, nitrogen and the low level of phenolic compounds recorded in cabbage and broad bean leaves. But when larvae fed with tomato and clover leaves caused a significant decrease in female pupal weight, growth index, and fecundity. This might be due to the poor nutritional quality in the tomato and clover leaves, poor content of carbohydrates, proteins and nitrogen as revealed by the phytochemical analysis [15]; or the ability of tomato leaves and clover leaves to manufacture proteinase inhibitors once stimulated by this chewing insect, resulting in an inhibition of insect's digestion of tomato and clover leaves, protein [16].

Data in **Table (6)** shows that high levels of both essential and non-essential amino acids in the hemolymph of the last larval instar of *S. littoralis* were obtained when the larvae fed on cabbage and broad bean leaves. Moreover, more decrement was observed as larvae fed on tomato leaves, and clover leaves. This decrease in the concentration of essential amino acids when larvae were fed on tomato leaves and clover leaves might be due to a deficiency in the metabolism of the amino acids [17]. The hemolymph of larvae fed tomato leaves is characterized by the absence of lysine, which is an essential amino acid, also alanine, cysteine, proline, and ornithine. Meanwhile, clover leaves were characterized by the absence of cysteine and proline. The amino acids were usually present in the diet as proteins, and the value of any ingested protein to an insect depends on its amino acid content and the ability of the insect to digest it. **Table (6)** showed that proteins contain 20 different amino acids, of which 10 of these are essential in the diet; the absence of anyone prevents growth. Although the other 10 amino acids are not essential, they are necessary for optimal growth. Their synthesis leads to conversion from essential amino acids resulting in energy-consuming [18].

Biochemical analysis of *S. littoralis* larvae fed on different host plants revealed the presence of proline only in the hemolymph of larvae reared on cabbage and broad bean; this might explain a higher mean number of eggs laid by the resulting female as proline increase the egg-laying capacity **Table (7).** Similar observations were stated by [19] for *Apis mellifera* queens as proline accounts for more than 50% of the total content of free amino acids in egg-laying capacity. The hemolymph of larvae fed tomato and clover leaves revealed the presence of taurine at a low level. This result was confirmed by [20], who detected taurine in the flight muscles of moth larvae of *Mamestra configurata* [21] found taurine in the flight muscles of *Schistocerca americana* gregaria, *Blatella orientalis*, and *Tenebrio molitor*. They stated that stress due to picrotoxin poisoning caused the release of taurine from the muscles into the hemolymph.

Based on nutritional values of instars of *S. littoralis*, development and reproductive capacity the present results revealed that the cabbage leaves might be the most favorable host for *S. littoralis* larvae followed by broad bean leaves. In contrast, tomato and clover leaves were the less favorable ones due to the differences in the leaf nutritional quality as mentioned during phytochemical analysis and the high level of amino acid in the hemolymph of larvae fed on cabbage and broad bean leaves. Finally, the suitability of selected host plants was classified from least to most suitable ranked as tomato > clover > broad bean > cabbage.

CONCLUSION

In conclusion, this result of the present study may add some more steps to put the host-plants effect against this insect. So, the host-plants can be involved in important steps necessary for successful IPM programs applied against *S. littoralis*.

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