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Research Article

Effect of Fertilization Level on the Tobacco Nutritional Quality and the Development, Nutritional Indices, Fecundity of *Spodoptera litura* (F.)

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ABSTRACT

Fertilization plays an important role in plant quality and can affect the biology characters of herbivorous insects indirectly. Tobacco planting was usually guided by appointed government organizations in China. A special compound fertilizer ($N:P_2O_5:K_2O$ is 1:1.2:2.5 in ratio) was recommended to use in many tobacco planting area. An experiment with treatments of five different fertilization levels (75(A), 90(B), 105(C), 120(D) and 135(E) kg/hm^2) was carried out to assess the nutritive qualities in tobacco leaves and influencing of development, nutritional indices and fecundity on the *Spodoptera litura* when reared on them. The results indicated that the *S. litura* larvae grew faster, and had longer female longevity and greater fecundity when reared on the tobacco leaves in fertilization level group C than those fed on the leaves in other groups significantly. Then we related this to the nutrient contexts of the leaves in the fertilizer using groups. The plants with higher soluble proteins, carbohydrates and the Relative Water Contents (FMC) in group C might be the important nutrition for development and reproduction. This investigation can provide a suggestion on this fertilizer application affecting the nutritive qualities in tobacco leaves and then the development and feeding behavior of the *S. litura* which feed with these qualities tobacco leaves can be influenced, the adults fecundity were shaped subsequently.

Keywords: Fertilization level; Tobacco; Nutritional indices; *Spodoptera litura*.

INTRODUCTION

Tobacco is a very important agricultural commodity due to its significant contribution to the national economy in many countries like China, America, India etc. [1]. But it is usually attacked by several species of insect pests especially the common cutworm (*Spodoptera litura*) causing heavy losses in the field. Insecticides were applied frequently to control insects in the field. The extensive use of synthetic pesticides has caused the soaring of resistance in insects. The residual pesticides have not only polluted the environment but also became a threat to human life [2]. Agronomic operations might provide potential tactics to manage insect populations. The chemical characteristics in the tobacco leaves are the important parameters to assess the tobacco qualities. This physical process in tobacco plant are affected heavily by textured soils especially the fertilizers management [3,4]. N mineralization in soils is also a most important factor to affect nicotine content in tobacco leaf [5]. Now, a special compound fertilizer ($N:P_2O_5:K_2O$ is 1:1.2:2.5 in ratio) was compelled to use in many commercial tobacco plant areas in China. How this agronomic operation affect the chemical contents in tobacco leaves will conduct an instructional fertilizer management. In agro-ecosystems, appropriate use of Nitrogen (N), phosphorus (P) and potassium (K) elements is of great importance to plant growth, development, high yield and significantly affects plant nutrition [6]. And here is growing evidence that dosages of fertilizers have been reported to have various effects on many insect populations in development, body size and weight, reproduction, survival rate and population abundance like Trialeurodes vaporariorum [7], Aphis gossypii [8,9], Bemisia argentifolii [10] Frankliniella occidentalis [11], Trogoderma granarium [12] and Tribolium castaneum [13], though the plant nutrition varies. So if the objective laws how the fertilizer application affect the physiology process of the *S. litura* were made certain, we would develop a precision agriculture operation for predicting and reducing this insect risk.

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Organisms can allocate limited resources to primary life functions including growth, reproduction and self-maintenance [14]. The nutritive values of host plants can affect the grow rate of insects, survival and thus influence the population dynamics of them [15,16]. The ability to grow and reproduce as fast as possible is crucial importance for many animals [17]. Food nutrition is a biological interpretation of the indices which related to their physiological base in insect. The 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) were the classic parameters which have been widely adopted in ecological, physiological and behavioral studies in insects [18]. The study of food nutritional indices of insects can help us to compare the performance of insects on various host plants [19]. So making clear the nutritional physiology of the *S. litura* when reared on tobacco leaves under different fertilization levels will be helpful to understand the mechanisms of this pest running rampant. The aim of this study is to determine how the fertilization amount influenced the tobacco leaves qualities. Then examine the influence of the tobacco leaves under different fertilization levels on the development, longevity and reproductive programming of the *S. litura* when reared on them.

MATERIALS AND METHODS

Insect rearing

The larvae were reared at 25 °C ± 1 °C and 60%-70% Relative Humidity (RH) with a 14:10 photoperiod on an artificial diet at the College of Agriculture, Yangtze University [20]. The adults were fed with 10% honey. In bio-assay, the larvae were transferred to tobacco leaves gently.

Tobacco plant and fertilizer

The tobacco plant (Yunyan 87) used in this study was provided by the Tobacco Research Institute of Hubei Province. And the research was conducted in the experimental fields of Agriculture at Yangtze University in Jingzhou, Hubei, China. A special compound fertilizer was produced by the Hubei Xiangqing Fertilizer LTD and recommended to use during the tobacco plant growing. Nutrient composition of the fertilizer is N: P_2O_5: K_2O is 1:1.2:2.5 in ratio of weight. In this study, five levels of fertilization, i.e., 75(A), 90(B), 105(C), 120(D), and 135(E) kg/hm^2, were employed and the fertilizer was applied to the fields 7 d before transplanting of the tobacco seedlings (Table 1).

Table 1: The fertilizer levels in different experimental groups.

Groups	Fertilizer (kg/hm^2)		
	N	P_2O_5	K_2O
A	75	84	175
B	90	108	225
C	105	126	262.5
D	120	144	300
E	135	162	337.5

Tobacco nutritional quality assays

For nutritive qualities detection, after the tobacco plants grown in the fields for 45d post-transplant, middle tobacco leaves were collected from the tobacco plants in different fertilizer applied respectively. Approximate 300 mg samples with 10 ml 0.2M PBS buffer (pH=7.0) was homogenized at 4 °C. The analytical method of soluble carbohydrates [21]. Briefly, the homogenates were incubated in boiling water for 30 minutes and filtered, then diluted to 100 mL with distilled water. 1 mL compound was drawn and centrifuged at 5,000 × g for 10 minutes. Then 0.5 mL anthracene copper, 1 mL water and 5 mL sulfuric acid (98%) were added to 0.5 mL supernatant. After the mixture was incubated in boiling water for another 10 minutes, the absorbance values were analyzed at 620 nm using a spectrophotometer (UV-5100 B, Shanghai China). The glucose was used as a standard. The analysis of soluble proteins concentration was conducted [22]. In summarily, the homogenates were centrifuged at 4,000 × g for 15 minutes at 4 °C. Then 100 μ L supernatant added 900 μ L distilled water and 5 mL Coomassie brilliant blue G-250. The absorbance values were detected at 595 nm using a spectrophotometer (UV-5100 B, Shanghai China). The Bovine Serum Albumin (BSA) was used as standard. Three seasons were repeated. The relative water content detection method [23]. About 1 g tobacco leaves collected from 5 different tobacco plants in each group were dried at 105 °C for 24 h in a dryer. The relative water content (FMC) was counted with the

Formula: FMC=(Fresh leaves weight-Dry leaves weight) ÷ Fresh leaves weight × 100%

Development and resulting female fecundity

Single newly hatched larva was transferred gently to Petri dishes (9.0 cm (diameter) × 1.5 cm (depth)) with tobacco leaves separately (each treatment repeated 50 individuals). And the leaves were changed two times a day until they pupated. The accumulated development time were added until the larvae pupated. Then the pupal duration were observed. After the emergence, 1 female and 2 male were put together for mating. Eggs of 15 individual females in each rearing group were counted and removed every day until the adults died, the total amount of eggs were added for statistical analysis. Three seasons were repeated.

Nutritional indices

After the larvae grow to 3rd on artificial diet, the 4th, 5th, 6th and 7th instars larvae were transferred gently to the tobacco leaves in different groups. Fifteen individuals were analyzed in each group at random. The food utilization indices values the Relative Consumption Rate (RCR), Relative Growth Rate (RGR), Approximate Digestibility (AD), Efficiency of Conversion of Ingested food (ECI) and Efficiency of Conversion of Absorbed food (ECD) were calculated adopted to the classical formulas as follows [24]. Three same seasons were repeated.

Relative Consumption Rate (RCR)=E/AT

Relative Growth Rate (RGR)=P/AT

Approximate Digestibility (AD) (%)=100(E-F)/E

Efficiency of Conversion of Ingested food (ECI) (%)=100 P/E

Efficiency of Conversion of Absorbed food (ECD) (%)=100 P/(E-F)

Where, A: Dry weight of animal during T, E: Dry weight of food eaten, F: Dry weight of feces produced, P: Dry weight gain of insect, T: Duration of experimental period.

Statistical analysis

All data were checked for normality via the Kolmogorov-Smirnov test before the analysis. The data were analyzed by one-way Analysis of Variance (ANOVA) with means separation at 5% level of significance by Tukey's test using IBM SPSS Statistics 25 (USA) soft-ware.

RESULTS

Effect of fertilizer on tobacco leaves nutritive qualities

In order to assess the biochemical components in the tobacco leaves of five fertilizer levels, the soluble carbohydrates, proteins and Relative Water Contents (FMC) were detected. The results indicated that the soluble carbohydrates ($F_{4, 10}$=4.53, p<0.005) and proteins contents ($F_{4,10}$=5.87, p<0.005) varied significantly between the fertilization levels, it had the similar tendency that they were increased with fertilizer amount used first and got down at a special level (group C). And the FMC were greatest in C and least in A ($F_{4, 10}$=4.83, p<0.005) (Table 2).

Larvae life cycle and adult fecundity

To determine whether the tobacco leaves of five fertilizer levels affect the larvae life cycle, duration of pre-pupae and pupae and longevity of adults, 50 individuals were reared on these leaves in each season. The results demonstrated that insects developed fastest when they fed on the tobacco leaves in group C followed by D,B,E and A ($F_{4,625}$=3.26, p<0.005). A similar result can be found at pre-pupae stage ($F_{4,592}$=3.13, p<0.005). But there was no significant difference on the pupae duration ($F_{4, 566}$=2.11, p<0.005). Female live longest in group C and shortest in treatment A but there is no effect on the longevity of male ($F_{4,225}$=3.17, p<0.005). Individual female laid more eggs when they fed tobacco leaves on treatment C ($F_{4,175}$=2.97, p<0.005) too. So the plant quality on fertilizer level C was more favorable for the *S. litura* development and reproduction (Table 3).

Feeding efficiency of larvae

When the larvae grew to 3rd on artificial diet, 15 individuals reared separately on the tobacco leaves in each fertilization level. After they grow to the 4th, 5th, 6th and 7th instars, various leave diets utilization indices were calculated to assess the nutritional indices. The results demonstrated that for the 4th instar, the RCR was greatest in insects fed on tobacco leaves in group E followed by D, C, B, A ($F_{4, 70}$=3.47, p<0.005). Greatest RGR values were found in E group and poor in group A and B ($F_{4, 70}$=3.31, p<0.005). On the AD index values, the food quality of tobacco leaves can be arranged with D, E, B, C, A ($F_{4, 70}$=3.52, p<0.005). ECI values were higher when the insects reared on leaves in groups A, B, C than those of the insects fed on the D and E groups (F4,70=2.91, p<0.005). But ECD value was greatest in group C and lowest in group E ($F_{4, 70}$=3.19, p<0.005) (Table 4).

During the 5th instar, the RCR values could be arranged with D, C, E, B, A (F4, 67=3.54, p<0.005). Higher RGR values were found for insects fed on tobacco leaves in group E, D, C and lower on group A and B(F4,67=2.74, p<0.005). Highest AD values were recorded fed on tobacco leaves fertilization level group A, then groups C, E, B and lowest on group D (F4,67=2.91, p<0.005). ECI values were higher for insects fed on leaves in groups A, B, C, E than group D (F4,67=3.11, p<0.005). ECD values were evident greatest on group C and least in group D (F4, 67=3.57, p<0.005) (Table 5).

When the insects grew to 6th instar, higher values of RCR were recorded for rearing on tobacco leaves in group C and lower in group A ($F_{4,61}$=2.54, p<0.005). For RGR values, greatest number appeared in group D and lowest in group A ($F_{4, 61}$=3.03, p<0.005). Approximate digestibility value was greatest when insects were fed with tobacco leaves in groups A, B, E ($F_{4, 61}$=3.12, p<0.005). The value of ECI was greater in insects fed on tobacco leaves in groups A and B whereas the value of this index was reduced in case of groups C, D, E fed insects ($F_{4,61}$=3.54, p<0.005). ECD values were higher on groups Band C and lower on treatment Dand E ($F_{4, 61}$=2.84, p<0.005) (Table 6).

After the insects reached 7th instar, greater values of RCR were recorded for feeding on tobacco leaves in groups E, Band A ($F_{4,57}$=3.33, p<0.005). For RGR values, the larvae reared on group E was found higher than other four groups ($F_{4, 57}$=2.63, p<0.005). There was no significant difference among all the groups for AD values ($F_{4, 57}$=3.24, p<0.005). Both the ECI ($F_{4, 57}$=2.44, p<0.005) and ECD ($F_{4, 57}$=2.71, p<0.005) values were higher in treatment C (Table 7).

Table 2: Soluble proteins, soluble carbohydrates and relative water contents (FMC) (mean ± SE) of tobacco leaves in five different fertilization level groups.

Fertilization levels	Soluble proteins (mg/g fresh weight)	Soluble carbohydrates (mg/g fresh weight)	Relative water contents (FMC) (%)
A	1.47 ± 0.06bc	0.98 ± 0.03c	78.80 ± 0.25d
B	1.61 ± 0.06bc	1.25 ± 0.05ab	81.93 ± 0.64c
C	1.94 ± 0.05a	1.37 ± 0.07a	85.27 ± 0.72a
D	1.71 ± 0.08b	1.14 ± 0.05bc	83.03 ± 0.48b
E	1.56 ± 0.08bc	1.03 ± 0.06c	81.03 ± 0.96c

Note: Mean values in a column followed by different lowercase letters are significantly different on the basis of analysis of variance with Tukey's test (p<0.05). A, B, C, D, E indicated five different fertilization levels respectively. Three same seasons were repeated.

Table 3: Larval duration, pre-pupal duration, pupal duration, female longevity, male longevity and fecundity (mean ± SE) of *Spodoptera litura* fed on the tobacco leaves in five different fertilization level groups.

Life cycle of larvae	n	A	n	B	n	C	n	D	n	E
I	150	3.28 ± 0.18a	150	3.1 ± 0.36b	150	2.64 ± 0.30d	150	2.83 ± 0.27c	150	2.74 ± 0.27cd
II	141	2.38 ± 0.05a	143	2.07 ± 0.05c	147	1.98 ± 0.05c	145	2.21 ± 0.05b	141	2.01 ± 0.04c
III	140	2.41 ± 0.04b	141	2.66 ± 0.08a	145	2.41 ± 0.13b	143	2.56 ± 0.04ab	139	2.52 ± 0.05ab
IV	135	2.40 ± 0.03b	136	2.49 ± 0.05b	143	2.32 ± 0.09c	137	2.53 ± 0.04a	137	2.54 ± 0.05a

V	132	2.65 ± 0.05a	131	2.62 ± 0.06a	137	2.53 ± 0.09ab	133	2.71 ± 0.07a	131	2.63 ± 0.05a
VI	128	2.61 ± 0.06a	126	2.59 ± 0.10a	134	2.54 ± 0.06a	129	2.49 ± 0.05a	127	2.50 ± 0.05a
VII	125	3.67 ± 0.07a	125	3.53 ± 0.05ab	131	3.12 ± 0.05c	128	3.38 ± 0.08b	121	3.55 ± 0.06ab
Total larval duration	-	19.39 ± 0.17a	-	19.06 ± 0.26b	-	17.54 ± 0.15d	-	18.70 ± 0.13bc	-	18.49 ± 0.16c
Pre-pupal duration	119	1.88 ± 0.03ab	120	1.90 ± 0.03a	125	1.53 ± 0.04d	122	1.86 ± 0.04ab	111	1.77 ± 0.03c
Pupal duration	113	11.24 ± 0.23a	111	11.03 ± 0.14a	125	10.80 ± 0.24a	115	10.72 ± 0.19a	107	11.02 ± 0.21a
Adult	-	-	-	-	-	-	-	-	-	-
Female longevity	46	9.79 ± 0.82b	45	10.81 ± 0.72b	49	12.36 ± 0.94a	47	10.73 ± 1.34ab	43	10.22 ± 1.11ab
Male longevity	58	6.20 ± 2.18a	56	7.78 ± 1.29a	61	8.60 ± 1.19a	58	5.77 ± 2.04a	49	9.68 ± 1.32a
Fecundity	36	839.38 ± 89.50b	36	899.50 ± 45.79b	36	1344.90 ± 108.26a	36	1230.50 ± 98.81a	36	913.57 ± 56.26b

Note: Mean values in a row followed by different lowercase letters are significantly different on the basis of analysis of variance with Tukey's test ($p<0.05$). The n value shows the sample size for each parameter. A,B,C,D,E indicated five different fertilization levels respectively. Three years same season experiment was combined.

Table 4: Mean (± SE) nutritional indices of *S.litura* fourth instar on tobacco leaves at five different fertilization levels.

Fertilization level	RCR(mg/day)	RGR(mg/day)	AD (%)	ECI (%)	ECD (%)
A	0.50 ± 0.03d	0.04 ± 0.01b	81.06 ± 1.21c	9.051 ± 0.49a	11.33 ± 0.78b
B	0.70 ± 0.03d	0.06 ± 0.01b	86.04 ± 1.50b	8.15 ± 0.816a	9.12 ± 1.06b
C	5.10 ± 0.27b	0.39 ± 0.03a	81.90 ± 0.68bc	8.00 ± 0.51a	15.26 ± 3.42a
D	8.45 ± 0.47a	0.36 ± 0.03a	89.30 ± 1.72a	4.84 ± 0.65b	5.27 ± 0.81c
E	1.48 ± 0.12c	0.38 ± 0.04a	54.38 ± 2.69d	8.31 ± 1.98a	10.01 ± 0.72b

Note: Mean values in a column followed by different lowercase letters are significantly different on the basis of analysis of variance with Tukey's test ($P<0.05$). RCR=Relative consumption rate. RGR=Relative growth rate. AD=Approximate digestibility. ECI=Efficiency of conversion of ingested food. ECD=Efficiency of conversion of absorbed food. A,B,C,D,E indicated five different fertilization levels respectively. Three same seasons were repeated.

Table 5: Mean (± SE) nutritional indices of *S.litura* fifth instar on tobacco leaves at five different fertilization levels.

Fertilization level	RCR(mg/day)	RGR(mg/day)	AD (%)	ECI (%)	ECD (%)
A	0.50 ± 0.03d	0.04 ± 0.01b	81.06 ± 1.21c	9.051 ± 0.49a	11.33 ± 0.78b
B	0.70 ± 0.03d	0.06 ± 0.01b	86.04 ± 1.50b	8.15 ± 0.816a	9.12 ± 1.06b
C	5.10 ± 0.27b	0.39 ± 0.03a	81.90 ± 0.68bc	8.00 ± 0.51a	15.26 ± 3.42a
D	8.45 ± 0.47a	0.36 ± 0.03a	89.30 ± 1.72a	4.84 ± 0.65b	5.27 ± 0.81c
E	1.48 ± 0.12c	0.38 ± 0.04a	54.38 ± 2.69d	8.31 ± 1.98a	10.01 ± 0.72b

Note: Mean values in a column followed by different lowercase letters are significantly different on the basis of analysis of variance with Tukey's test ($P<0.05$). RCR=Relative consumption rate. RGR=Relative growth rate. AD=Approximate digestibility. ECI=Efficiency of conversion of ingested food. ECD=Efficiency of conversion of absorbed food. A,B,C,D,E indicated five different fertilization levels respectively. Three same seasons were repeated.

Table 6: Mean (± SE) nutritional indices of *S.litura* sixth instar on tobacco leaves at five different fertilization levels.

Fertilization levels	RCR(mg/day)	RGR(mg/day)	AD (%)	ECI (%)	ECD (%)
A	0.10 ± 0.01c	0.02 ± 0.01d	68.48 ± 1.22a	18.82 ± 0.89a	27.78 ± 1.40b
B	1.77 ± 0.12ab	0.30 ± 0.02c	56.97 ± 2.96c	17.42 ± 1.18a	33.81 ± 2.16a
C	2.58 ± 0.11a	0.39 ± 0.02b	66.20 ± 2.28ab	15.70 ± 1.09b	36.57 ± 3.98a
D	1.56 ± 0.15b	0.50 ± 0.02a	55.21 ± 2.15c	14.57 ± 2.61b	24.45 ± 2.18c
E	2.17 ± 0.57ab	0.25 ± 0.03c	61.51 ± 1.66bc	14.97 ± 1.74b	24.42 ± 2.40c

Note: Mean values in a column followed by different lowercase letters are significantly different on the basis of analysis of variance with Tukey's test ($P<0.05$). RCR=Relative consumption rate. RGR=Relative growth rate. AD=Approximate Digestibility. ECI=Efficiency of Conversion of Ingested food. ECD=Efficiency of Conversion of Absorbed food. A,B,C,D,E indicated five different fertilization levels respectively. Three same seasons were repeated.

Table 7: Mean (± SE) nutritional indices of *S.litura* seventh instar on tobacco leaves at five different fertilization levels.

Fertilization levels	RCR(mg/day)	RGR(mg/day)	AD (%)	ECI (%)	ECD (%)
A	1.24 ± 0.08ab	0.21 ± 0.02b	45.67 ± 4.22a	15.98 ± 0.75a	38.58 ± 4.12bc
B	1.51 ± 0.05a	0.19 ± 0.02b	51.29 ± 2.00a	12.35 ± 0.99b	24.33 ± 1.99c

C	1.07 ± 0.22bc	0.15 ± 0.04b	46.93 ± 12.48a	17.81 ± 4.52a	59.50 ± 13.15a
D	0.77 ± 0.12c	0.15 ± 0.05b	38.63 ± 10.95a	17.03 ± 1.27a	61.75 ± 18.48a
E	1.41 ± 0.13ab	0.26 ± 0.02a	49.25 ± 2.60a	15.49 ± 2.91a	36.98 ± 4.10bc

Note: Mean values in a column followed by different lowercase letters are significantly different on the basis of analysis of variance with Tukey's test ($p<0.05$).RCR=Relative Consumption Rate. RGR=Relative Growth Rate. AD=Approximate Digestibility. ECI=Efficiency of Conversion of Ingested food. ECD=Efficiency of Conversion of Absorbed food. A,B,C,D,E indicated five different fertilization levels respectively. Three same seasons were repeated.

DISCUSSION

Fertilizers are being extensively used to produce high-quality crops, which can increase a plant's nutritional quality and attractiveness to phytophagous insects [25,26]. Nitrogen supplementation causes vigorous plant growth [27]. It is an important component of many structural, genetic and metabolic compounds in plant cells and also one of the most important performance limiting factors of herbivores insect [28]. Evidence had shown that Phosphorus may be a much more important component for the determinant of fecundity in some phytophagous insects [29, 30]. Potassium nutrition also plays a critical role in plant growth and alters host plant quality for [31]. In this study, the soluble carbohydrates and proteins contents can be raised with the amount of fertilization firstly. But after getting a peak, they would get down again. And the Relative Water Content (FMC) values had a similar tendency (Table 2). These results might have reflected the physiological, biochemical and molecular responses of the plant to the conditions, including the amount of the fertilizer.

In this research, we only concerned how the application of fertilizers affected on the tobacco nutritional quality and biology performance of the *S. litura*. And do not consider the yield and flavor of tobacco leaves. It is also a defect in our research that we fail to measure nicotine content in the tobacco leaves under the different fertilization level group, nicotine is another important factor to regulate plant defense against herbivory [32].

Fertilizers application can affect insect development and population densities by regulating plant nutritive qualities indirectly [33,34]. Different nutritive values of host plants can influence the development rate and population dynamics of insects also [35]. Insects feeding on protein-rich plants will develop more quickly than those which consume plant material containing less protein [36,37]. Carbohydrate is essential material for insect growth and energy source. Evidence had found that diets with higher carbohydrate will enhance life span [38]. Water content has been shown to be a limiting factor when the caterpillars grow. A lower growth rate was observed when larvae fed with plants containing less water content [39]. In this study, the tobacco leaves in fertilization level group C had the highest contents of the soluble carbohydrates, proteins and water (Table 2). In addition, the larvae eating the tobacco leaves in group C grew faster and longer female adults longevity than those which fed with the leaves in other groups might be related to the higher nutritive chemistry and water in them (Table 3). So higher the soluble carbohydrates, proteins and relative water contents in tobacco leaves might play an important role for the *S. litura* development and reproduction.

Numbers of eggs of *S. litura* produced by the female adults varied greatly on different food and differ under different environment [40,41]. In this study, numbers of eggs laid by one single female adult ranged from 839 on group A to 1344 on group C (Table 3). This result is very similar to [42]. The S. litura female adults oviposited an average of 2540 eggs on the artificial diet in our lab.

Nutritional indices were measured using forth to seventh instars because they were more measurable than the primary instars. For nutritional indices determining, the larger larvae were used in the Helicoverpa armigera [43] and the Cnaphalocrocis medinalis [44].

The utilization of diets by insects is determined by its capacity to ingest, assimilate and convert food into its body tissues [45]. High efficiency of food conversion of digested food means low food consumption to growth, A lower ECD value indicated higher metabolic maintenance costs [46]. Nutritional performance of insects can be influenced by not only the quality and quantity of consumed diet [47], but the physiochemical properties of the food they fed [48]. The relatively high AD might cause by the high water content. And lower water content in plant leaves can induce a lower efficiency of nutrient digestion [49]. The best diets not only can provide the applicable nutritive materials but can also be assimilated and converted into energy and structural substances for the insect developing [50]. In the present study, the high contents of most of the measured nutrients might have been reflected that the high consumption indices when the insect fed on the leaves in group C.

In most insects, the adult reproductive capacity is mainly dependent on nutrients accumulating when they are yang [51]. In this research, a longer longevity and high fecundity rate was observed in the resulting females reared on tobacco leaves in group C compared with the other groups, but no significantly effect on the longevity of males and the female adults lived longer than males (Table 3). Similar results were reported when *S. litura* reared on cotton. Report also indicated that *S.litura* male adults lived longer than females and differ on different host plants, and this difference might be affected by temperature.

The total larval developmental time of *S. litura* larvae has six-seven instars, in this study, the total larval duration on tobacco leaves ranged from 17.54 to 19.39 d (Table 3). These time were coincided with the obtained by [52]. But they should be, however they shorter than those obtained by. In this study, *S. litura* performed seven instars [53]. But reported that it developed six instars.

It is concluded that the fertilizer application is a vital measure to improve tobacco leaves qualities. However, sometimes it is paradoxical that higher nutritive qualities may cause population outbreaks for polyphagous insects [54]. So we proposed fertilizer application at a scientific knowledge guide.

CONCLUSION

The present study found out that the soluble proteins, carbohydrates and the relative water contents can be affected by the amount of fertilizer application significantly. The *S. litura* larve like to eat the tobacco leaves applied fertilizer with 105 kg/hm^2 much more and grow more quickly. They will give more offspring when grow up.

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CONFLICT OF INTEREST

We declare that we have no conflict of interest.

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