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Effect of Different Temperatures and Hosts on Biology of the European Corn Borer, *Ostrinia nubilalis*(Hübner), in Laboratory Conditions

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ABSTRACT

The European corn borer *Ostrinia nubilalis* (Hübner), as a worldwide corn pest, causes serious damages. In the present study, some biological aspects of *O. nubilalis* were investigated on three different host plants including corn stalks, potato, and soybean stems, and a specific semi-artificial diet. Once appropriate host was selected, developmental rates of eggs, larval and pupal stages as well as moth emergence, longevity, and female fecundity were determined at four constant temperatures (20, 24, 28, and 32±1°C). The relationship between temperature and developmental rate was estimated with two linear models under laboratory condition (70-80% RH and a photoperiod of 16L:8D hour). Results showed significant differences between studied foods, such that corn stalk sections and semi-artificial diet were appropriate host for *O. nubilalis* compared to the other two hosts. It was also revealed that optimum temperature for growth of this pest was 28°C. Lower developmental threshold estimated by traditional and Ikemoto-Takai linear models for whole immature stages were about 9 and 10°C, and thermal constants were 473 and 431 degree day (DD), respectively. Compared to previous studies, these values were similar in the immature stages, except for the larval stage, which could indicate the importance of nutrition and role of the plant host in temperature requirements.

Keywords: Corn pest, Host plant, Artificial diet, Temperature requirements, Linear models.

INTRODUCTION

The European corn borer, *Ostrinia nubilalis* (Hübner), is one of the most damaging pests found in many cultivated areas of corn (EPPO, 2014). *O. nubilalis* may attack young corn plants or the other cultivated plants and weeds early in the season before the corn invasion, and its first generation spends on such hosts (Anderson *et al*., 1984; Raspudić *et al*., 2013). Afterward, the next generations occur on corn and larvae cause direct losses by boring into plant stalks in addition to indirect losses through facilitating the infection by microorganisms such as *Fusarium* spp. (Taghizadeh and Basiri, 2013; Blandino *et al*., 2015). Various methods are used to control *O. nubilalis* in the corn fields. Methods such as chemical control or cultural control have been used in the past, but now, more environmentally friendly methods such as biological control, using host-plant resistance, or pheromones are preferred (Bazok and Barcic, 2010; Vincent *et al*., 2013). Sterile Insect Technique (SIT) is another method that has recently been considered in *O. nubilalis* management programs (Rosca and Barbulescu, 1996;

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Bloem and Carpenter, 2001).

In Iran, most studies have been conducted on various aspects of another corn stem borer, namely, *Sesamia cretica* Led. (Lep.: Noctuidae). Like European corn borer, *S. cretica* is present in cornfields and damages the corn crop (Soltani Orang *et al*., 2014), but it can also cause serious damages to sugarcane, which is a highly important plant in some parts of Iran (Yaghubi *et al*., 2015; Ehtesham nia, *et al*., 2017). However, some studies have been conducted about the effects of pheromone-baited traps (Pélozuelo *et al*., 2006), maize hybrids (Sharifi ziveh *et al*., 2009), different insecticides (Azarmi *et al*., 2015) or intercropping systems (Tavakoli *et al*., 2013; Fathi, 2016, 2018; Zarei *et al*., 2019) on *O. nubilalis* in Iran.

It should be noted that investigations on biology, behavior, and other aspects of an insect species as well as success of any insect pest control program, especially biological control, SIT, and breeding resistant varieties depends on continuous supply of high-quality insects in adequate numbers. Therefore, it is necessary to determine optimal rearing conditions. A few number of studies have been conducted on the effect of different diets on *O. nubilalis*. Gahukar (1976) studied the effect of several artificial diets on biology of European corn borer and considered the factors such as ease of use, costs, and biological parameters of reared insects and recommended a diet containing corn meal of whole grain for borer rearing. In a study series, Barbulescu (1984a, b; 1990; 1993; 1994) identified an optimal diet for mass rearing of *O. nubilalis* over successive generations. Developmental stages, egg production of the female moth, longevity, and fertility of the eggs were studied on the corn borer reared on another semi-artificial diet (Salama, 2009). Likewise, Saad *et al*. (2012) compared effectiveness of two semi-artificial diets and a natural corn diet on some biological aspects of *O. nubilalis* during immature stages as well as adults.

There are also some useful studies on temperature requirements and temperature-based developmental models of this insect, which have been often validated under field condition (Anderson *et al*., 1982; Got *et al*., 1996; Trnkaa *et al*., 2007).

Therefore, most previous studies on *O. nubilalis* biology can be divided into two main groups. In one series of studies, different artificial diets used in mass rearing of this insect have been investigated, and in the second series of studies, the effects of different plant hosts on insect biology in “field conditions” have been investigated, of which the data were used in the prediction models of the pest field population. Hence, it seems that there is no comprehensive study on biology of *O. nubilalis* in presence of different foods and at different temperatures as well as its temperature requirements in “laboratory conditions”. Therefore, in the present study, we aimed to investigate the effects of three host plants, which are among the preferred hosts of this pest (Anderson *et al*., 1984; Gomboc, 2003; Taghizadeh and Basiri, 2013), and an artificial diet on development and fecundity of *O. nubilalis*. Once appropriate food was identified, developmental rates of eggs, larval, and pupal stages at four constant temperatures were determined. In addition, as for first time, two linear models, traditional and Ikemoto-Takai linear models, were used to describe the relationship between temperature and developmental rate and estimating optimal temperature and temperature thresholds in order to provide better understanding of biology and determine an optimum condition for rearing of *O. nubilalis*.

MATERIALS AND METHODS

Host Plants and Artificial Diet

Three different host plants including corn stalks (*Zea mays* L. cultivar SC-704), potato (*Solanum tuberosum* L. cultivar Volvox) and soybean (*Glycine max* (L.) cultivar Harsoy-63) and an artificial diet, were used in the experiments. Seeds of host plants were provided from Seed and Plant Improvement Institute (Karaj, Iran) and planted in experimental plots (18 m^2: 6×3 m) in the greenhouse. Plants were generally irrigated two times a week and after about 4 months, plant stems were used for rearing of the insects.

A semi-artificial diet (Table 1, Georgescu *et al*., 2015) was used to rear *O. nubilalis* in the laboratory. Prepared diet was distributed into each rearing transparent plastic container (6×14×20 cm).

Table 1. Ingredients of the semi-artificial diet (Georgescu *et al*., 2015).

Ingredient	Quantity
Bean flour	572 g
Wheat bran	160 g
Beer yeast	156 g
Premix[a]	40 g
Sugar	155 g
Ascorbic acid	15,6 g
Sorbic acid	10 g
Glacial acetic acid	14,8 mL
Formaldehyde	8,4 mL
Agar	40 g
Distilled water	3500 mL

[a] A combination of different vitamins, aminoacids, Aminovit®, and Zagrospharmed.

Insects

Different instar larvae were collected from infested cornfields in Dashte-Naz, Sari, Mazandaran Province, Iran (36.6° N, 52.1° E; 16 m height) and were transferred to plastic containers containing each of the host plants or the diet. Stems of host plants were cut into 10 cm sections and were replaced daily with new ones. Besides, for better settling of larvae, surface of artificial diet was scraped when the diet was cooled down. After two generations, the pests reared on different hosts were used in the experiments.

The fifth instar larvae entered the pupal stage within the stems or plastic straws, which were placed inside the container. Each pupa was transferred to small plastic jars (80 mL) using moistened cotton balls until the adult moths emerged. One pair of female and male moth (the male moths were darker in color) was released into a cylindrical oviposition cage (25 cm height with a diameter of 17 cm). The cages were covered on their top and inner side using non-woven polypropylene cloths and accordion fold along with paper ribbons hung from top edge of the cages. To provide the food, cotton wool moistened with honey solution (10%) was placed in each cage. The cages were kept in climatic rooms (GRR SET 20000 G, Grouc, Iran) at 70-80% of RH and photoperiod of 16:8 (L:D) hours under different constant temperatures of 20, 24, 28 and 32±1°C. These temperatures were selected based on some similar previous studies and preliminary experiments. Every other day, number of laid eggs was counted. For each temperature, 100 eggs were transferred to a separate petri dish kept in incubator (Binder MKF 240, Germany) under the same conditions. Newly hatched larvae were transferred to the determined host containers. Duration and mortality of developmental stages were measured as well as mortality and longevity of female and male moths.

A data logger (TES 1384, data logger 4 Input Thermometer, Taipei, Taiwan) was used to monitor the temperature. One pair of female and male moth was deposited in the Insect Collection of the Department of Entomology, Tarbiat Modares University, Tehran, Iran (TMUC).

Mathematical Models and Data Analysis

The lower developmental threshold and thermal requirements of *O. nubilalis* were estimated using the traditional and Ikemoto-Takai linear models. The linear models have been used widely to estimate the lower developmental threshold (T_{min}) and thermal constant (K) of arthropods (Campbell *et al*., 1974; Lactin *et al*., 1995). The Ikemoto-Takai equation is derived from the traditional linear model to obtain more reliable estimates of the parameters (Ikemoto and Takai, 2000). These two linear formulas are shown in the following equations (Campbell *et al*., 1974; Ikemoto and Takai, 2000):

The traditional linear model:

$$D = K/(T - T_{\min}) \quad (1)$$

Ikemoto-Takai linear model:

$$DT = K + T_{\min} \times D \quad (2)$$

Where, D indicates the Duration of development (days), T, ambient Temperature (°C), T_{min}, the lower Temperature threshold and K is the thermal constant. The latter function was proposed by Ikemoto and Takai (2000).

The traditional and Ikemoto-Takai linear models were analyzed using ArthroThermoModel (ATM) software developed by Mirhosseini *et al*. (2017) under MATLAB 2018. The SE of T_{min} and K in Ikemoto-Takai linear model were obtained directly from the regression analysis; but in the traditional model, the standard errors were calculated from the following equation (Campbell *et al*., 1974; Karimi-Malati *et al.*, 2014; Atapour and Osouli, 2017):

$$SE_{T\min} = \frac{y_m}{b} \times \sqrt{\left(\frac{S^2}{N \times y_m{}^2}\right) + \left(\frac{SE_b}{b}\right)^2} \quad (3)$$

$$SE_K = \frac{SE_b}{b^2} \quad (4)$$

Where, y_m is the average value of the developmental rate, b is estimated slope of fitted line, S^2 is the residual mean Square of the linear model, and N is the sample size.

Data from all tests were submitted to Shapiro Wilk test to verify for normality, as well as to Levene's test for equality of variances. Differences between treatments were determined by one-way Analyses Of Variance (ANOVA), followed by a Tukey’s test for multiple comparisons at $P< 0.05$ using the SPSS (Version 16.0; IBM Company) software. All data were expressed as mean±SE.

RESULTS

Results from the experiments conducted on different hosts showed no significant difference between corn stalk and artificial diet at developmental period of immature stages by significant difference with other hosts (Table 2). The calculated total duration and mortality of immature stages were about 27-28 days and 13%, respectively, in these hosts. However, these values increased to about 37 days and 25% in potato stems.

Similarly, number of eggs laid by females, moth emergence, and longevity was significantly higher in corn stalk and artificial diet (Table 3). Since there was no significant difference between the corn stalk and artificial diet, the corn stalks were used in subsequent experiments due to ease of access and reduction of the costs. Table 4 shows results obtained regarding the effect of four constant temperatures on developmental period of eggs, larva, and pupa as well as mortality in such immature stages. Development time at each temperature showed significant differences during incubation, larval and pupal period as well as total of immature stages. In general, total duration of immature stages was significantly shorter at 32°C, however, mortality percentage was higher (47%) at this temperature. In general, both values of developmental period or mortality of immature stages of *O. nubilalis* were high at 20°C. Developmental period of eggs, larva, pupa, and total duration of immature stages was 2.4, 16.9, 6.4, and 25.6 days, respectively, at 28°C. However, developmental period at this temperature was longer than the temperature of 32°C, but mortality was lower than the other temperatures.

Number of eggs laid by females and moth longevity were significantly influenced by the tested temperatures (Table 5). Both female and male moths showed the highest emergence at 28°C, the highest oviposition rate was also observed at this temperature with an average of 199.2 eggs per female.

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Table 2. Developmental time (days) of immature stages (mean±SE) and mortality (%) of *Ostrinia nubilalis* in different hosts at 28°C.[a]

Host	Egg			Larvae			Pupae			Total		
	n	Incubation period	Mortality (%)	n	Larval period	Mortality (%)	n	Pupal period	Mortality (%)	n	Duration	Mortality (%)
Artificial diet	100	2.7±0.1 c (1-6)	5	95	18.4±0.2bc (13-23)	4.2	87	6.8±0.2 b (4-10)	4.4	100	28.1±0.3 c (21-36)	13
Corn stalk	100	2.3±0.1 c (1-4)	4	96	17.6±0.3 c (11-23)	3.1	87	6.9±0.2 b (4-10)	6.4	100	27.1±0.3 c (21-35)	13
Soybean stem	100	3.1±0.1 b (1-6)	8	92	19.5±0.2 b (15-25)	7.6	78	7.08±0.1b (5-10)	8.2	100	29.7±0.3 b (23-36)	22
Potato stem	100	3.7±0.1 a (2-6)	10	90	24.8±0.4 a (18-38)	7.7	75	7.9±0.2 a (5-11)	9.6	100	36.8±0.5 a (28-51)	25
F		36.63			123.08			8.43			132.66	
df		3, 369			3, 348			3, 323			3, 323	
P-value		< 0.001			< 0.001			< 0.001			< 0.001	

[a] Means followed by the same letter in each column are not significantly different using Tukey's test at P< 0.05 in each column. Values in parenthesis are the minimum and maximum values.

Table 3. Number of eggs laid by each female (mean±SE), percentage of emergence (%), and longevity (mean±SE) of *Ostrinia nubilalis* in different hosts at 28°C.[a]

Host	n	No of eggs per female (Mean±SE)	Female			Male		
			n	Moth emergence (%)	Longevity (Days) (Mean±SE)	n	Moth emergence (%)	Longevity (Days) (Mean±SE)
Artificial diet	30	199.2±6.4 a (123-187)	30	90	8.5±0.2 a (7-11)	30	93.3	7.3±0.3 a (4-10)
Corn stalk	30	202.4±3.2 a (180-256)	30	93.3	8.6±0.2 a (7-10)	30	93.3	7.3±0.2 a (5-10)
Soybean stem	30	148.6±2.9 b (114-185)	30	76.6	7.2±0.3 b (5-10)	30	70	7.1±0.4 a (4-10)
Potato stem	30	138.0±2.8 b (110-169)	30	66.7	6.3±0.3 c (4-9)	30	70	5.7±0.3 b (4-8)
F		65.81			19.99			7.80
df		3, 116			3, 94			3, 94
P-value		< 0.001			< 0.001			< 0.001

[a] Means followed by the same letter in each column are not significantly different using Tukey's test at P< 0.05 in each column. Values in parenthesis are the minimum and maximum values.

Table 4. Developmental period of immature stages (egg to pupa) and mortality of *Ostrinia nubilalis* at studied temperatures on corn stalks.

Stage	Temperature (ºC)	n	Mortality (%)	Developmental time (days) Mean±SE [a]	Min	Max	F	df	P-value
Egg	20	100	31	7.62±0.1 b	2	8			
	24	100	26	5.16±0.1 c	2	8			
	28	100	13	2.40±0.1 d	1	6			
	32	100	16	2.04±0.1 d	1	4	853.55	3, 310	< 0.001
Larva	20	69	18.8	27.4±0.2 b	16	29			
	24	74	9.4	22.1±0.2 c	11	29			
	28	87	8	16.9±0.1 d	14	23			
	32	84	20.2	15.2±0.1 e	12	25	843.05	3, 266	< 0.001
Pupa	20	56	17.8	10.9±0.1 b	6	13			
	24	67	4.4	7.95±0.1 c	4	10			
	28	80	7.5	6.39±0.1 d	4	10			
	32	67	20.8	4.67±0.1 e	4	7	370.14	3, 233	< 0.001
Total	20	100	54	45.8±0.3 b	27	46			
	24	100	36	35.2±0.3 c	21	44			
	28	100	26	25.6±0.2 d	21	36			
	32	100	47	21.7±0.2 e	21	32	1397.2	3, 233	< 0.001

[a] Means followed by the same letter in each column are not significantly different using Tukey's test at P< 0.05.

Table 5. Fecundity, percentage of emergence and longevity of *Ostrinia nubilalis* at studied temperatures on corn stalks.[a]

Temperature (ºC)	n	No of eggs per female (Mean±SE)	Female n	Female Moth emergence (%)	Female Longevity (Mean±SE)	Male n	Male Moth emergence (%)	Male Longevity (Mean±SE)
20	30	48.2±1.3 d (34-63)	30	63.3	14.89±0.6 a (10-20)	30	76.6	10.3±0.5 a (7-15)
24	30	147.9±4.2 b (98-192)	30	76.6	10.4±0.4 b (8-15)	30	80	9.04±0.4 a (6-14)
28	30	199.2±6.4 a (123-287)	30	90	8.55±0.2 c (7-11)	30	93.3	7.46±0.3 b (4-10)
32	30	107.3±3.3 c (74-150)	30	63.3	6.89±0.4 d (4-9)	30	56.6	6.47±0.4 b (4-10)
F		227.99			67.72			19.31
df		3,116			3, 84			3, 88
P-value		< 0.001			< 0.001			< 0.001

[a] Means followed by the same letter in each column are not significantly different using Tukey's test at P< 0.05 in each column. Values in parenthesis are the minimum and maximum values.

However, longevity decreased significantly with increase in the temperature, from 14.9 to 6.9 days in females and from 10.3 to 6.4 days in males at 20 and 32°C, respectively.

Table 6 shows the regression equation estimates for both traditional and Ikemoto-Takai linear models, adjusted coefficients of determination (R^2_{adj}), T_{min} and K for each developmental stage. Developmental rate increased linearly as temperature increased and both models were fitted to the studied variables (R^2_{adj}> 80%). Values of T_{min} and K estimated by traditional model were less than Ikemoto-Takai model (Table 6).

Table 6. The estimated lower Temperature threshold (T_{min}), thermal constant (K), adjusted coefficients of determination (adj R^2) and regression equations for various immature stages (egg to pupa) of *Ostrinia nubilalis* reared on corn stalks by traditional and Ikemoto-Takai linear models.

Linear model	Stage	Regression equation	T_{min} (°C)	K (DD)	R^2_{adj}	P-value
Traditional	Egg	DR= -0.591+0.035T	16.79±2.1	28.41±4.4	0.81	< 0.01
	Larva	DR= -0.015+0.002T	5.78±2.05	388.87±35.1	0.86	< 0.01
	Pupa	DR= -0.115+0.010T	11.37±1.96	98.19±10.01	0.84	< 0.01
	Total	DR= -0.021+0.002T	9.93±1.2	472.71±30.27	0.92	< 0.01
Ikemoto-Takai	Egg	DT= 26.84+17.54D	17.54±0.18	26.83±0.78	0.96	< 0.01
	Larva	DT= 305.5+10.08D	10.08±0.37	305.52±7.6	0.83	< 0.01
	Pupa	DT= 76.99+14.54D	14.54±0.4	76.99±3.07	0.82	< 0.01
	Total	DT=431.51+11.32D	11.33±0.24	431.51±8.05	0.88	< 0.01

Based on traditional and Ikemoto-Takai models, the T_{min} values of total immature period were equal to 9.9 and 11.3°C, respectively, and *O. nubilalis* required 472.7 and 431.5 DD, respectively, above a lower threshold temperature for its development from egg to adult emergence (Table 6).

DISCUSSION

Some studies have been previously carried out to determine a suitable artificial diet for mass rearing of *O. nubilalis*. For this purpose, developmental rates of different stages of this insect have been measured on a specific diet and often at a constant temperature (Gahukar, 1976; Barbulescu, 1993, 1994; Salama, 2009; Saad *et al*., 2012). These studies were slightly different in terms of ingredients of administered diet, however, corn, beans, or wheat flour were often found in most of these diets (Barbulescu, 1993; Salama, 2009; Saad *et al*., 2012).

Natural plant hosts have received less attention for rearing of European corn borer, therefore; there is little information about biology of *O. nubilalis* in presence of other hosts. Results of this study showed that both corn stalk and semi-artificial diet used in our study were suitable for rearing of this pest. Incubation period, larval and pupal stages were about 2.5, 18, and 7 days, respectively, in these hosts, similar to the values reported in the study by Gahukar (1976), especially on wheat germ and corn meal (whole grain) artificial diets at the same temperature (27-28°C). In addition, developmental periods and egg production calculated in a study on an artificial diet containing kidney bean at 30°C (Salama, 2009) are relatively similar to the values obtained from semi-artificial diet in our study at 32°C. Developmental period of immature stages reported in this study (Salama, 2009) was a little shorter and egg production was higher (188.2±4.1) compared to those obtained in the current study.

Considering the short immature developmental stages, low mortality during all life span, and high oviposition of females, corn stalk sections as well as artificial diets can be exploited in rearing of *O. nubilalis.* Although it was predicted that corn stalk was the most suitable host among the plant hosts, our studies showed that artificial diet introduced by Georgescu *et al*. (2015) as well as corn stalks, could be used in laboratory studies or pest mass rearing. The literature review on different diets used for rearing of *O. nubilalis* shows that most of them had good results. Therefore, it seems that the purpose of rearing, availability of materials, and costs where insects are being used are important issues in determining the type of diet or host. Since corn stalks were available in the current study and, therefore, were cheaper and more facile than artificial diet, they were used in further experiments. It should be noted that mass rearing on plant hosts in the long term requires proper timing between plant and insect growth. Thus, in such circumstances,

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using artificial diets is, perhaps, more logical despite being more expensive.

The pattern of thermal sensitivity of developmental rate of immature stages in *O. nubilalis* in the present study followed this general tendency, with growth rate increasing gradually as temperature increased from 20 to 32°C. Mortality decreased from 20 to 28°C, but it again increased at 32°C. It seems that small size and ectothermic physiology of insects can elevate or lower body temperature to lethal levels during high or low temperatures, respectively (Rinehart *et al*., 2000; Mironidis and Savopoulou-Soultani, 2010). Water balance at these temperatures complicates the situation too (Denlinger and Yocum, 1998). Considering these results together with moth emergence, longevity, and female fecundity, it can be concluded that optimum temperature for rearing of this insect is 28°C. In this study, however, four "constant temperatures" were evaluated for all stages of *O. nubilalis.*

Regarding mass rearing of European corn borer in successive generations, Georgescu *et al.* (2015) applied a temperature range at different stages: 27-28°C for larval stage, 21-25°C for pupal stage, 18 hours at 27-28°C and 6 hours at 20°C for incubation period on a diet as used in our study. They showed that, after several consecutive generations in laboratory, reared insects had sufficient quality to cause damages at corn plants in field conditions. Although the temperature of 28°C was determined as an optimal growth temperature in our study, it seems that this insect can be well reared in a "proper temperature range" in conditions where it is not possible to keep the temperature constant.

The T_{min} values of 10 and 11°C (using the traditional and Ikemoto-Takai models, respectively) estimated in the current study for total immature period are close to 10°C, as employed in many models of *O. nubilalis* populations (Got and Rodolphe, 1989; Kelker *et al.,* 1990). In addition, the lower temperature threshold for eggs estimated in our study (about 17°C) was relatively close to 15°C as reported in the study by Capinera (2000). However, calculated T_{min} in traditional model for larvae and pupae in our study (about 6 and 11°C, respectively) was different from 11 and 13°C reported by Capinera (2000), but T_{min} estimated by Ikemoto-Takai model in our study (10 and 14°C, respectively) was similar to what was reported in Capinera study. Although differences, especially in larval stage, could be due to the food resources influencing thermal requirements (Lee and Roh, 2010), but it seems that the parameters calculated in "Ikemoto-Takai model" in our study are generally close to previous studies.

Anderson *et al*. (1982) investigated *O. nubilalis* developmental rates of immature stages over a temperature range of 15-35°C in three different hosts including cornstalk sections, snap bean pods, and an artificial diet. They plotted separate developmental curves for each host, and then they used these curves to develop models for prediction of moth emergence in field conditions. According to their results, models based on developmental data using different hosts led to different results in field studies. Therefore, it can be concluded that quality of the host, in addition to temperature, influences growth curve and, consequently, prediction models.

CONCLUSIONS

Our results provided fundamental information for some biological parameters of *O. nubilalis* in presence of different hosts and temperatures as well as its thermal requirement, which will be used in other biological and toxicological studies, or control strategies requiring sufficient volume of insect population. Four key findings were revealed in the present study: (1) Cornstalk sections as well as semi-artificial diet had acceptable performance as a host for rearing of this species, (2) Optimum temperature was 28°C with the most rapid developmental rate and lowest mortality in immature stages and highest

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moth emergency and female fecundity, (3) T_{min} value of the total immature period of pest reared on corn stalk sections was about 10-11°C and this species required about 430-470 DD before adult emergence stage, and (4) Lower development thresholds and thermal requirements calculated in each life stage were also influenced by the host, therefore, both temperature and host data should be used in developing predictive models for *O. nubilalis*. It is suggested that during future studies, more temperatures treatments be examined to provide more accurate developmental rate and critical temperatures for *O. nubilalis*.

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تأثیر دما و میزبان های مختلف بر زیست‌شناسی کرم اروپایی ذرت *Ostrinia nubilalis* (Hübner)، در شرایط آزمایشگاهی

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چکیده

کرم اروپایی ذرت، *Ostrinia nubilalis* (Hübner)، به عنوان یک آفت ذرت در سراسر جهان باعث خسارت‌های جدی می‌شود. در مطالعه حاضر، برخی جنبه‌های زیست شناسی *O. nubilalis* روی سه گیاه میزبان مختلف شامل ساقه ذرت، ساقه سیب زمینی و سویا و یک رژیم غذایی نیمه مصنوعی مورد بررسی قرار گرفت. پس از انتخاب میزبان مناسب، طول دوره رشد تخم، لارو و شفیره و همچنین میزان ظهور و طول عمر شب‌پره‌ها و تخم‌ریزی حشرات ماده در چهار دمای ثابت (۲۰، ۲۴، ۲۸ و۳۲ درجه سلسیوس) تعیین شد. رابطه بین دما و نرخ رشد و نمو با دو مدل خطی در شرایط آزمایشگاهی (رطوبت نسبی ۷۰-۸۰ درصد و دوره روشنایی ۱۶ ساعت) برآورد شد. نتایج نشان داد که بین غذاهای مورد مطالعه تفاوت معنی داری وجود دارد، به طوری که ساقه ذرت و رژیم غذایی نیمه مصنوعی در مقایسه با دو میزبان دیگر میزبان مناسب‌تری برای *O. nubilalis*بودند. همچنین مشخص شد که دمای مطلوب برای رشد این آفت، ۲۸ درجه سلسیوس است. دمای آستانه رشد توسط مدل خطی سنتی و Ikemoto-Takai برای کل مراحل نابالغ به ترتیب ۹-۱۰ درجه سلسیوس و ثابت حرارتی ۴۷۳ و ۴۳۱ روز-درجه برآورد شد. در مقایسه با مطالعات قبلی، این مقادیر در مراحل نابالغ به جز مرحله لارو مشابه بودند که می‌تواند نشان‌دهنده اهمیت تغذیه و نقش گیاه میزبان در نیازهای دمایی این حشره باشد.

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