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Monitoring The Population Density Of The Diamondback Moth Plutelila Xylostella Using Growth Degree Days

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Abstract

This study was conducted to develop monitoring programs for diamondback moth Plutelila xylostella in Basrah province. Four cultivars of Cabbage (Karmizi, Hanar, Dalal and Hortus) were planted to determine the population density of the insect during the growing season of 2020/2021. The highest density of larvae was recorded on Dalal cultivar, while the lowest density was found on Hanar cultivar. The first appearance of the moth was recorded in Zubair region in the second week of December with an average of 0.13 larvae/plant. The population of larvae increased reaching the peak (8.53 Larva/ plant) in the fourth week of February, then the density decreased to 5.21 larvae/ plant in the fourth week of March. The first appearance of pupae was recorded in the second week of December (0.92 larvae /plant). The number of pupae increased reaching the peak in the fourth week of February (6.83 larva /plant), then the density decreased to 4.9 larvae /plant in the fourth week of March. In order to develop pest control programs using Growth Degree Days, laboratory experiments were conducted to determine the appropriate temperature for the development of the insect from among the temperatures (20, 25, 30, 35° C). The longest incubation period of eggs (the highest average of development) was 4.33 days at 20° C, and decreased to 3 days at 35° C. The development period of the larva was 12 days at 20° C, and decreased to 8 days at of 25° C, then to 5 days at 30° C. However, all larvae were killed at 35° C. For the pupal stage, the developmental period reached 6 days at 20° C and decreased to 4 days at 25° C, then the pupal stage decreased to 4 days at 30° C. The appearance of DBM was predicated by accumulative temperature (Degree days) modeling in Basrah province that was set at 18.6 DDs.

Introduction

Diamondback moth DBM (Plutella Xylostella) is a dangerous pest for cruciferous crops worldwide, where the number of its generations varies according to the host plant, geographical distribution, and the temperature ranges (Alizadeh et al., 2011). The number of DBM generations varies per year, reaching four generations in temperate regions and 20 generations in tropical regions (Shelton, et al.,2004, Capiner, et al., 2001; Roux, et al., 2006; Vickers et al., 2004).

Development time of insects are affected by the environmental factors (temperatures and moisture). Temperature has an effect on survival, longevity, and reproduction of the insects (Hallman and Denlinger 1998); Liu et al. (2002) revealed to the effect of temperature on the DBM survival and growth periods from egg to adult when the insect was reared at temperatures between 10-30° C. Golizadeh et al., (2009) indicated that the lifespan of DBM adult females ranged from 12.9 days at 30° C to 30.4 days at 10° C on cauliflower and 9.7 days at 30 °C to 40.0 days at 15 °C on broccoli. Waqar et al. (2017) also confirmed the effect of the host on DBM egg development periods of the insect was reared on different hosts under laboratory conditions at 25 ± 2 °C, 50-

60% RH and photoperiod of 16:8 hours (light: dark). Ngowi et al. (2017) indicated that the optimum temperature for the development of diamondback moths is 32.5, 33.5 and 33° C for eggs, larvae and pupae, respectively. Mortality rates increased due to extreme temperatures to 35.3, 70.0 and 52.4% for eggs, larvae and pupae, respectively, and the highest reproduction rate was 87.4 females/generation at 20°C. In addition, the moth survival and development increased with decreasing temperature.

Thus, any model which is based on temperature can more accurately estimate the dynamics of insect population, and can realistically predict the occurrence of pest and save the time and resources needed to check the field. The simplest way to explain the effect of temperature on the development of insects is determination the relationship between the rate of development (1/the duration of development) and temperature, then calculating the lower threshold LDT (lower development threshold) which is the degree to which growth stops, as well as in calculating the thermal constant). Finally, estimating SET (Sum of effective temperatures) which are the number of thermal units (DDs) that fall above the minimum and necessary thermal threshold for the development of each insect species (Ibrahim, 2014). Golizadeh et al. (2007) determined the development of DBM at (10, 15, 20, 28, 28, 30, 30, 32.5 and 35° C) with relative moisture 65% and 14:10 hours (light: dark) on two plants cauliflower and cabbage for estimating LDT represented at 7.06 ° C and 7.84 ° C respectively, and DDs were 263.74 and 261.51 degrees of cauliflower and cabbage respectively. Ibrahim et al. (2014) studied the development of DBM in a laboratory on a plant at four temperatures (20, 25, 30, 35° C), relative humidity 65%, and a photoperiod of 12:12 hours (light: dark) to determine the minimum thermal threshold and thermal constant for growth and development stages. The results showed the thermal constant value were 80.64, 90, 66.31, 181.18, and 44.64 degrees for the egg, larva, pupa, male and adult female stages, respectively.

The present study determine the DBM population density on different cabbage varieties and compare the influence of a range of temperature on the development times of DBM, The objective is to develop a DDs model for predicting the occurrence of pest.

Methods and Materials

Monitoring the population density diamond back moth.

A field experiment was carried out at Zubayr region/ Basrah province (N:0756 978, . E: 336 3356) during the growing season 2020-2021. This study was conducted to determine the population density of DBM on four cabbage varieties (Table 1). The field (450 m^2) was divided into 3 blocks; each block was divided into four experimental units, which were 30 m^2 (12x2.5 m), with 80 cm. alleys, arranged in a randomized complete block design with 3 replicates. The seasonal occurrence and population density of the DBM were studied weekly starting from the first week of November 2/11/2020 until the second week of March 14/3/2021; the samples were taken randomly by taking 3 plants from each experimental unit for each treatment separately. The population density of larvae, and pupae. The temperatures and relative humidity were obtained from the weather station, Al-Barjisiya research station, province of Basrah. The effect of weather factors on the population density of the insect during the agricultural season was studied by studying the correlation between temperature, relative humidity and the densities of larvae and pupa in the field.

Diamondback moth colony

Samples were collected from a cabbage field during the growing season of 2020/2021 at Zubair region/ Basrah province. For preparing a colony, the insects was maintained on cabbage leaves inside wooden box (25 x 25 x 45 cm), placed inside the growth chamber at 25° C and photoperiod of 16:8 hours (light: dark); the leaves most affected by feeding the insect were replaced whenever needed.

The effect of temperature on DBM life cycle

The insect life cycle was studied in the laboratory at four temperatures (20, 25, 30, 35 ° C) at relative humidity of approximately (65±5%), and photoperiod of 16:8 hours (light: dark) by using a growth chamber (Rumed, made in Germany). Eggs were collected from container containing DBM adult that were isolated from the breeding boxes. 30 eggs were collected 24-48 hours after being laid by the female, and were placed in transparent plastic petri dishes 9 x 9 cm (3 dishes for each temperature). Then, incubation period of eggs and percentage of hatching, development of the larval, pupal, and adult have been studied.

Determining the minimum temperature threshold and Degree Days required for the development of diamondback moth larvae.

After measuring the developmental time of the diamond-back moth instars, the developmental threshold was determined by calculating the regression equation between temperatures and the developmental rate at the mentioned temperatures by calculating the regression equation:

y=a+bx

Y = daily development rate

a = the point of intersection with the y axis.

b = regression factor

The critical temperature for evolution can be estimated when y=0, and the critical temperature is:

$$x = \frac{a}{b}$$

whereas :

x = critical temperature for evolution.

The heat units required for the development of insect roles were calculated according to Arnold's method (1960) because it is simple and accurate compared to other methods (Ahmad, 1979):

DDs = (Experimental constant temp. - threshold temp.) x Mean development time

whereas:

(Degree Days) DDs = accumulated daily thermal units

Experimental constant temp. = The constant temperature at which laboratory experiments were performed

Threshold temp. = critical temperature for development.

Mean development time = average development time

For the purpose of determining the date of the appearance of the full insect in the field, the heat collection equation for each day was used according to the method of Arnold (1960) based on the minimum and maximum temperatures for the agricultural season 2020/2021, which were obtained from the weather station Al-Barjisiya Research Station in the Zubair region:

DDs= (max+min/2)- threshold temp.

Where:

DDs = accumulated daily thermal units.

max = the maximum temperature.

min = the minimum temperature.

threshold temp = critical temperature for development

Results and Discussion

Population density of the diamondback moth

The first infestation of DBM larvae was recorded the second week of December at Zubair site (temperature 14.65 m and relative humidity 65.06%), with an average of 0.13 larvae/plant, and the number of larvae increased to reach its peak in the fourth week of February (16.35° C and relative humidity 39%); the density reached 8.53 Larva/plant, then the density decreased in the fourth week of March (31.79° C and relative humidity 29.4%), with an average of 5.21 Larva/plant (Fig. 1)

The results of Table (1) showed that there were significant differences in the population of larvae density on the verities during the growing season. The highest density of larvae was recorded in the fourth week of February on the variety Dalal, (18.13 Larva/plant), and the lowest density of larvae was in the first week of December on the varieties Kirmizi and Hanar, which reaching to 0 Larva/plant.

While the appearance of pupae at Zubair site was in the second week of December (temperature 14.32 and relative humidity 73%) with an average of 0.92 pupae/plant. The number of pupae increased to reach the peak in the fourth week of February (16.35° C and a relative humidity of 39%), with an average of 6.83 pupae / plant; then the density decreased in the fourth week of March (31.79 ° C and relative humidity 29.4%) , with an average of 4.9 pupae / plant (Figure 2).

The results of Table (2) indicated that the highest density was recorded in the fourth week of February on the Dalal cultivar, reaching 14.94 pupae/plant, and the lowest density of pupae was in the first week of December on Hanar variety (0 pupae/plant).

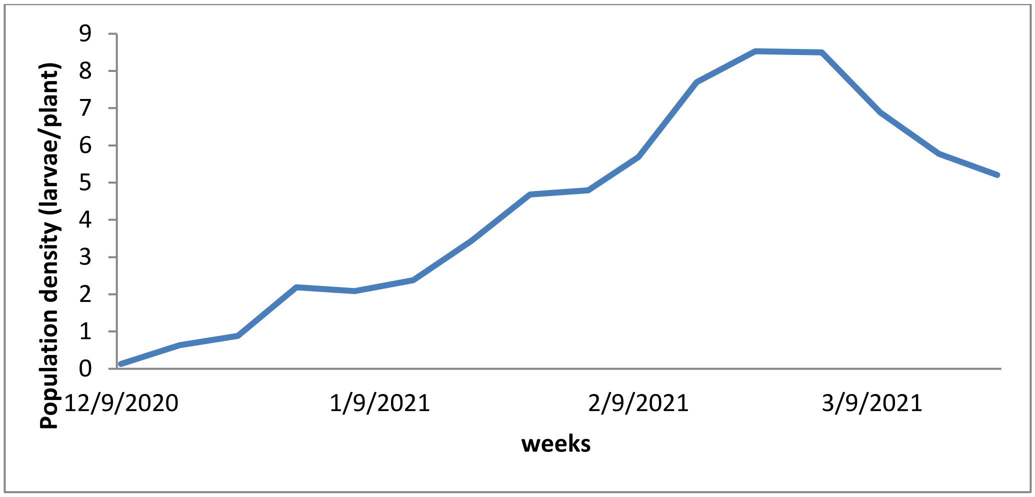

Figure (1) Population density of DBM larvae during the growing season 2020/2021; LSD value (α=0.05) =0.541

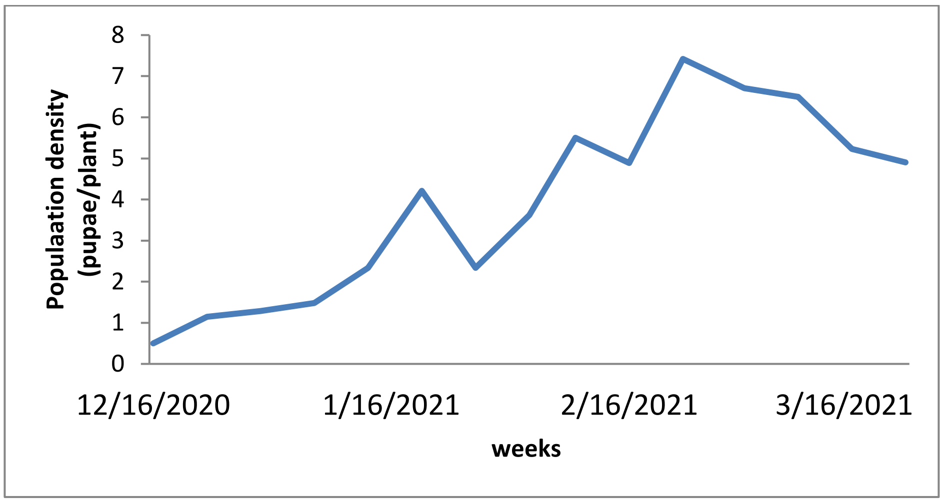

Figure (2) Population density of DBM pupae during the growing season 2020/2021; LSD value (α = 0.05) =0.492

Table (1) Population density of DBM on cabbage variety during the growing season 2020/2021.

Week	Population density of DBM on cabbage variety (larvae / plant)			
	Hortus	Hanar	Dalal	Kirmizi
09/12/2020	0.083	0	0.444	0
16/12/2020	1.083	0.25	1.02	0.16
23/12/2020	1.667	0.13	1.5	0.25
30/12/2020	4.056	0.44	3.69	0.58
06/01/2021	2.944	0.63	3.91	0.86

13/01/2021	3.111	1	4.52	0.88
20/01/2021	5.22	0.63	7.13	0.77
27/01/2021	7.47	0.55	10.22	0.5
03/02/2021	7.88	0.33	10.33	0.611
09/02/2021	9.19	0.44	12.38	1
16/02/2021	13.44	0.61	16	1.13
23/02/2021	14.83	0.5	18.13	1.3
03/3/2021	13.47	0.49	16.86	0.75
10/3/2021	11.77	0.36	16.83	0.55
17/3/2021	9.69	0.25	12.8	0.36
24/3/2021	8.55	0.25	11.72	0.33
L.S.D	1.082			

Table (2) Population density of the DBM pupae on different cabbage varieties during the growing season 2020/2021.

Week	Population density of DBM on cabbage variety (Pupae / plant)			
	Hortus	Hanar	Dalal	Kirmizi
09/12/2020	0.19	0	0.22	0.08
16/12/2020	0.69	0.3	0.88	0.11
23/12/2020	0.22	0.25	1.72	0.36
30/12/2020	2.16	0.3	2.47	0.22
06/01/2021	2.19	0.52	2.52	0.69
13/01/2021	3.44	0.41	4.97	0.55
20/01/2021	7.3	1.16	7.63	0.75
27/01/2021	3.38	0.41	4.8	0.77

03/02/2021	4.86	0.44	7.41	0.75
09/02/2021	8.66	0.44	11.58	0.86
16/02/2021	7.47	0.44	10.41	0.97
23/02/2021	12.55	0.41	15.77	0.63
03/3/2021	10.94	0.38	14.94	0.58
10/3/2021	10.94	0.47	13.97	0.55
17/3/2021	8.94	0.33	11.11	0.41
24/3/2021	8.11	0.25	10.83	0.41
LSD	0.984			

The effect of temperature on the DBM lifecycle

The results of the effect of temperature on the period of egg hatching (Table 4) showed that the shortest period of eggs hatching was 4.33 days at 20° C, and decreased to 3 days at 35° C. the effect of temperature in the larval stage was recorded, an increase in the speed of the development of the larval instar was observed with increasing temperatures, and the development period of the larva reached 12 days at 20 ° C, then decreased to 8 days at 25 ° C, and reached 5 days at 30 ° C; All larvae were killed at 35°C. The period of pupal stage development reached 6 days at 20 ºC, and decreased to 4 days at the 25 ºC, then the period of the pupae stage decreased to 3 days at 30 ºC. The effect of temperatures (30-25-20) ºC was recorded in the development period of the adult, which reached to 13, 11 and 11 days, respectively.

The present results revealed to the ideal temperature for the development of the all insect stages which was 20 ° C; where the incubation period of eggs was the least, and the duration of the development of other stages was reduced. This is in agreement with Ngowi1 et al. (2017), who confirmed that a temperature of 20°C is the most suitable degree for the survival of eggs, larvae and pupae. Marchioro and Foerster (2012) stated that the peak of egg laying for moths occured at 20 ºC, and the highest intrinsic rate of natural increase occurs between 20 and 25 ºC.

Table (4) The effect of temperature on the DBM life cycle in the laboratory

Temperature	The effect of temperature on the period of development of the phase(day)			
	egg	larvae	pupae	adults
20	4.333	12.00	6.00	13.00
25	3.000	8.00	4.00	11.00

30	2.000	5.00	3.00	11.00
35	2.000			
LSD	0.7909	1.370	1.370	1. 631

Determining minimum temperature threshold and Degree Days required for the development of diamondback moth larvae.

The results of the study of the relationship between the rate of daily development of the stages of the diamondback moth for each of the egg, larva, pupae and adults and temperatures (35-30-25-20°C) using regression equations (r2 = 0.63, 0.86, 0.66 and 0.86, respectively, Figs. 3-6); the minimum temperature thresholds were found to be 8.091, 2.891, 5.456 and 4.117 °C for the egg, larva, pupae and adult, respectively, at the optimum temperature of 20 °C, respectively, Comparing with the minimum temperatures of the moth at a temperature of 25 °C for the egg, larva, pupa and adult 11.559, 4.180, 8.98 and 4.861 °C, respectively. The minimum temperatures of the moth at a temperature of 30 °C for the egg, larva, pupae and adult 17.53, 7.52, 13.33 and 5.49 °C respectively, While the minimum temperature was recorded at 35 °C for the egg only, reaching 17.538 °C. The correlation coefficient for each of the egg, larva, pupae and adult was 0.7711, 0.8873, 0.668 and 0.9456, respectively. Then, the cumulative heat units (Degree Days) required for the development of the stages of the DBM egg, larva, pupae, and adults were calculated: 53.03, 162.84, 44.22 and 105 units/day at the optimum temperature of 20 °C (Table 5).

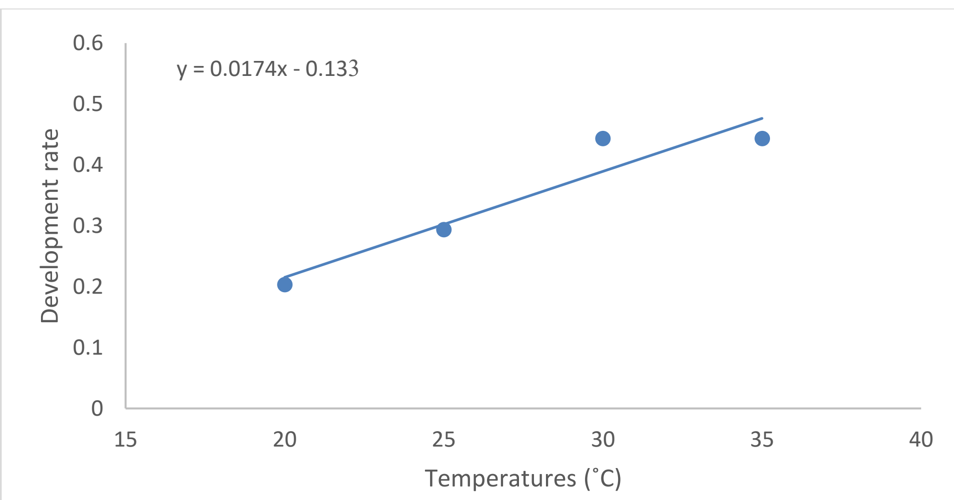

Figure (3) The relationship between the rate of development rate of egg hatching of the DBM and constant temperatures.

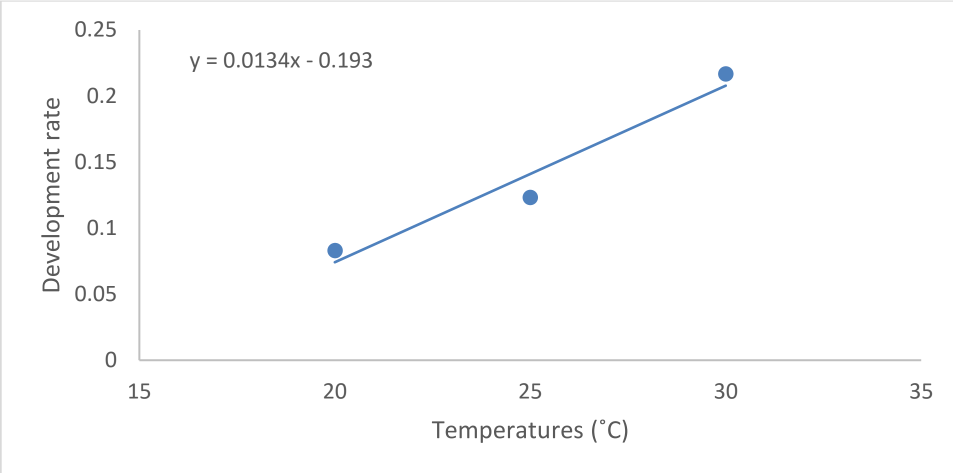

Figure (4) The relationship between the daily development rate of DBM larvae and constant temperatures.

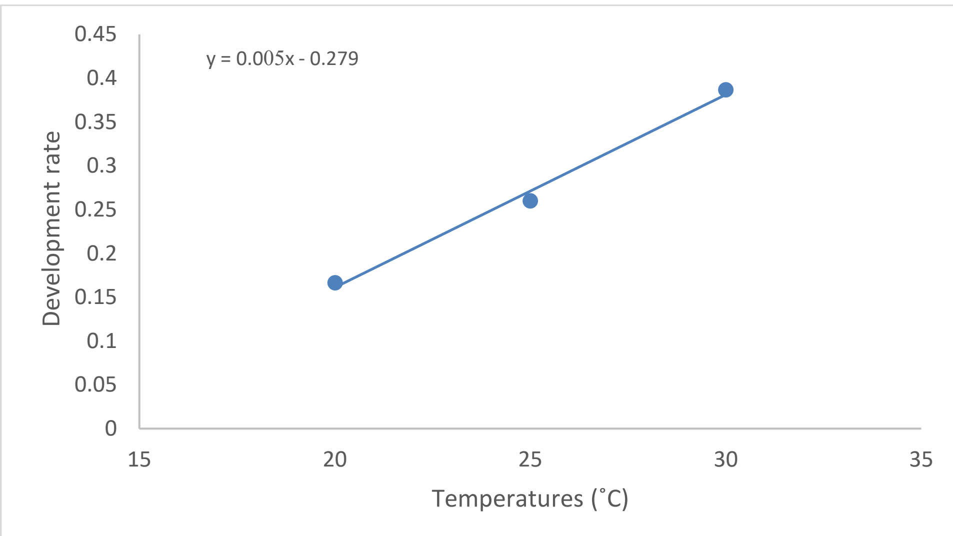

Figure (5) The relationship between the daily development rate of DBM pupae and constant temperatures.

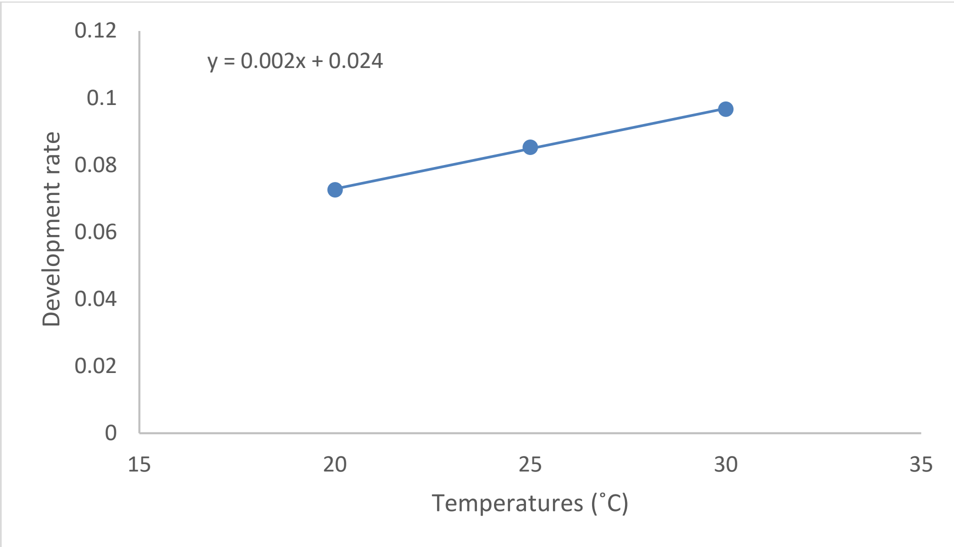

Figure (6): The relationship between the daily development rate of the DBM adults and the constant temperatures.

Table (5) Average of accumulative thermal units (DDs) required for the development of the DBM under different constant temperatures.

temperature	Thermal units accumulated for the diamond-back moth			
	egg	larvae	pupae	adults
20	53.03	162.84	44.22	105
25	75	200	100	300
30	60	150	90	300
35	70	0	0	0

Determining the thermal requirements necessary for the development of the diamondback moth helps in early prediction of its appearance and monitoring it in the field before reaching the level of economic damage. Table (6) shows that the average heat units (DDs) required for the appearance of the diamondback moth in the Zubair area, that is 18.6 heat units on 12/7 2020 and 12/9/2020, respectively.

Table (6) The accumulated thermal units required for the appearance of the diamondback moth and reaching the peak at the Cabbage field during the growing season 2020/2021.

Appearance	Peak

cumulative Thermal units(DDs)	Date	cumulative Thermal units (DDs)	Date
18.65	2020/12/9	14.95	2021/2/24

Ngowi et al. (2017) mentioned that the average estimated minimum temperatures for the development of the DBM (eggs, larvae, and pupae are 4.21,4.79,3.76 ºC, respectively, and the degree days for eggs, larvae and pupae were calculated as 22.4, 58.5 and 37.1 DD respectively; the optimal values were The temperatures for eggs, larvae and pupae are 32.5, 33.5 and 33 ºC, respectively, thus, the results indicated that the temperature range 20-25°C is the optimum limit for natural increase and the maximum net reproductive rate. Sarnthoy et al. (1989) reported that the intrinsic rate of increase of a moth depends on temperature. The temperature of 17.6 ºC gave the highest rate for moths. Sarkar (2007) showed that the moth was the most abundant during the period from January to February, when the minimum temperature ranged from 21.1 to 31.40 ºC and 7.9 to 19.90 ºC, respectively. Patra et al. (2013) confirmed that the first appearance of the moth (2.80 Larva / plant) was on January 19, 2012, and it reached its peak (13.60 Larva/ plant) on March 1, 2012; in southern and southeastern Brazil. Campos et al. (2006) confirmed that the temperature has an effect on the emergence and peak of the diamondback moth and varies from one region to another.

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