The Accumulated Heat Units Required for the Development of the Different Stages of the Grape False Spider Mite, *Tenuipalpus granati* Sayed Under Laboratory Conditions

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Abstract

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The grape false spider mite *Tenuipalpus granati* Sayed (Acariformes: Tenuipalpidae) is one of the significant pests on the grape trees in Iraq. The aim of this study was to determine the threshold temperature and calculate the heat units needed for the development time of the duration of this mite stage. Different incubation temperatures (10 15, 20, 25, 30, 35, and 40±2°C), relative humidity (50-60±5%), and light:darkness period of 16: 8 hours were applied to rear this mite on the lower surface of the newly grown grape leaves. The results showed that the development time of the egg, larva, protonymph, and deutonymph (active, quiescent, active + quiescent) at temperatures 15, 20, 25, 30, and 35°C were decreased gradually with temperature increase. Furthermore, the development time of the eggs incubation period was 15.3, 4.98 days and the larva (active + quiescent) were 15.1, 4.43 days, and the protonymph (active + quiescent) was 14.4, 3.48 days and of the deutonymph (active + quiescent) was 15.6, 5.58 days for the effect of 15 and 35°C. Additionally, the development time from egg to adult was 60.00 and 18.26 days at 15 and 35°C, respectively. The threshold temperature was 6.73, 7.89, 9.38, 6.47 and 7.3 °C, respectively. Finally, the accumulated heat units required for the development time of each mite instar varied according to the threshold temperature difference and development time.

Keywords: False red mite, heat units, *Tenuipalpus granai*, developmental rate.

Introduction

The grape false spider mite, *Tenuipalpus granati* Sayed, belongs to the family Tenuipalpidae and is prevalent in many countries of the world including Iraq. It affects significantly pomegranates and grape trees (Mesa *et al*., 2009). However, in Iraq, it attacks different grape varieties that show various sensitivity to infestation with this mite (Jeppson *et al*., 1975). The larval, protonymph, deutonymph and adult feed on the lower surface of the leaves, absorbing plant succulents. It spends the winter season in the egg and adult stages to avoid the influence of lower temperatures. On the other hand, in the greenhouse, it continues reproducing without wintering throughout the year. It was noticed that the development period decreases with increasing temperature. For example, its life cycle takes about three weeks at a temperature of 25˚C (Zhang, 2003). Thus, the relationship between temperature and the development time of mites was investigated in several studies to understand the nature of development of cold-blooded animals. This is because the temperature is necessary for their biochemical reactions (Allen, 1976; Pedigo, 1999; Steel & Torrie, 1960). The correlation between the changes of development time and temperature can be calculated using specific regression equation (Andrewarth & Birch, 1954).

However, it was not possible to rely on the normal temperature only in clarifying some biological relationships such as the dates of emergence of mites and insects. Therefore, the threshold temperatures necessary for the development of individuals and the dates of their appearance were adopted through a special system called the Degree Days system of thermal units (D.D.S) by recording the daily thermal aggregation of thermal units that were above the threshold temperature (Arnold, 1960). It was discovered that the mite species differ in their thermal requirements to reach the stage of maturity. At each life stage, a specific development threshold is required and without it, no development can occur. There was a relatively wide range of temperature required for the different stages of development (called the effective heat) (Steel & Torrie, 1960), and a regression equation has been applied as an effective way of determining the developmental threshold, which was one of the essential matters in calculating the thermal requirements for growth and development (Andrewarth & Birch, 1954). In spite of the importance of this subject regarding mites, no such study was conducted on the grape false red mite *T. granati* in Iraq. Thus, the aim of the current study was to determine the threshold temperature of the development time and the heat units needed for its development under laboratory conditions.

Materials and Methods

The eggs obtained from the matings of the *T. granati* mites females and males were reared on the lower surface of the newly grown grape leaves. They were individually distributed in Petri-plastic dishes following the Al-Jboory and Taha method (Al-Jboory & Al-Suaide, 2010) under different temperatures (10, 15, 20, 25, 30, 35 and 40±2°C), relative humidity (50-60±5%), and photoperiod of

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light:darkness of 16: 8 hours. Ten replications were used for each treatment. The development time of the different mite stages, the preoviposition period (eggs), the longevity of females and the number of eggs/female were recoded. The development of the mite was measured by the time spent for the development of its instar that was estimated in days and called the development time, from which the development rate was found according to the equation (1/ Development time). Whereas, the constant temperature (Campbell *et al*., 1974) was determined by extracting the linear relationship using the linear regression equation Y=a+bx (Y=Development rate, a,b = constant factors).

The threshold temperature (x) for development when Y = 0 can be estimated according to the following equation Y = - a / b. The thermal units of mite development were calculated according to the Arnold method (Arnold, 1960) as follows: Degree Days (D.D.s) = Experimental constant temperature - threshold temperature x mean development time. The completely randomized design (CRD) was used to implement the experiments, and the data obtained were analyzed statistically using ANOVA and Duncan Multiple Range Test at P=0.05 (Steel & Torrie, 1960).

Results and Discussion

Effect of constant temperatures on the developmental time required for the different stages of the false red grape mite, *T. granati* Sayed

The results obtained (Table 1) showed that temperatures 15, 20, 25, 30 and 35˚C had an apparent effect on the development time (days) of the egg's incubation period, which were 15.3, 11.23, 8.83, 6.025 and 4.98 days, respectively, and there were no significant differences between the effect of the first four temperatures, but differed significantly with the effect of 35°C. The duration of active larva instar was 10.6, 7.35, 4.5, 3.35 and 2.55 days, for the five different temperatures, respectively. The quiescent larva was 4.50, 2.80, 2.85,1.53 and 1.88 days, respectively, the total period of development of the larva (active+quiescent) was 15.1, 10.23, 7.33, 4.88, and 4.43 days, for the five different temperatures, respectively, and there were no significant differences in the development time duration of the active larva and quiescent larva reared under the first three temperatures, but was significantly different from the effect of 30 and 35°C. Active protonymph duration was 9.6, 6.80, 3.50, 3, and 2.23 days, respectively, and the duration for the quiescent protonymph was 4.8, 2.70, 1.93, 1.73, and 1.25 days, for the different temperatures, respectively. Thus, the total period of development of the protonymph (active+quiescent) was 14.4, 9.6, 5.43, 4.73, and 3.48 days, for the different temperatures, respectively.

The development time for the active deutonymph was 10.4, 9.43, 4.73, 2.73, and 3.7 days, and for the quiescent deutonymph was 5.2, 3.03, 2.48, 1.78 and 1.98 days, for the five different temperatures, respectively. Thus, the total development time for the deutonymph (active+quiescent) was 15.6, 12.48, 7.18, 4.6 and 5.58 days, for the five different temperatures, respectively.

As for the total development time from egg to adult, it was 60.00, 43.22, 28.28, 20.33 and 18.26 days, for the five temperatures, respectively, with no significant differences recorded for the first four temperatures, but they differed significantly with development at 35 ˚C. When Childers *et al.* (2009) examined the life cycle of the mite *Eutetranychus banksi* (McGregor) at various temperatures, females developed from egg to adult males in 29.6, 17.2, 13.1, 11.6, 11.7 and 9.6 days at 15, 20, 25, 28, 30 and 32°C, respectively. Developmental time of both sexes were significantly different (P<0.05) at each temperature. Wildaniyah *et al.* (2018) explained that the population density of *T. pacificus* increased with increasing temperature and relative humidity had the same effect as the temperature on the life span of mite species. Furthermore, Zaher and Yousif (1972) reported that the population density of *T. granati* reached the highest value at the temperature of 29.8-34.5°C and relative humidity of 61.6-67.5%, whereas Yousef *et al.* (1980) confirmed that the shortest development time needed for the instar of the false red grape mite *T. granati* was between 29.8 and 30.7°C. In this study no results were obtained when mites were raised at 10 or 40°C.

As for the preoviposition period (eggs), the longevity of female and the number of eggs/female (Table 2), the preoviposition period (eggs) for this mite was 10.80, 5.86, 2.73, 2.34 and 1.8 days when reared under 15, 20, 25, 30 and 35°C, respectively, with no significant differences recorded at 15 and 20°C, but with significant difference with higher temperatures used. The developmental stage of females were 35.6, 25.1, 22.8, 17.48 and 11.5 days, when reared at the five different temperatures mentioned above, respectively, with no significant differences recorded at the first four temperatures, but differed significantly when reared at 35°C. The number of eggs/female was recorded at an average of 7.5 eggs at 15°C, with a significant difference with the other four temperatures, which reached 14.29, 11.5, 18 and 17.83 eggs/female, respectively.

Table 1. The effect of different temperatures on the egg developmental period (days) of the *T. granati* Sayed mite.

Temp. °C	Incubation (Egg)	Larva			Protonymph			Deutonymph			(Egg - Adult)
		Active	Quiescent	Total	Active	Quiescent	Total	Active	Quiescent	Total	
15	15.3 A	10.6 A	4.5 A	15.1 A	9.6 A	4.8 A	14.4 A	10.4 A	5.2 A	15.6 A	60.0 A
20	11.23 A	7.35 A	2.8 A	10.23 A	6.8 A	2.7 A	9.6 A	9.43 A	3.05 A	12.47 A	43.22 A
25	8.83 A	4.50 A	2.85 A	7.33 A	3.5 A	1.925 A	5.43 A	4.735 A	2.48 A	7.175 A	28.28 A
30	6.025 A	3.35 B	1.53 B	4.88 B	3.0 B	1.73 B	4.73 A	2.73 B	1.78 B	4.6 B	20.3 aA
35	4.975 B	2.55 B	1.88 B	4.43 B	2.23 B	1.25 B	3.48 B	3.70 B	1.98 B	5.58 B	18.23 B

Values followed by the same letters in the same column are not significantly different at P= 0.05, using Duncan's multiple range test.

Table 2. The effect of different temperatures on the developmental preoviposition period, female longevity, and the number of eggs per female of *T. granati* Sayed under laboratory conditions.

Temp. ºC	Preoviposition period (days)	Longevity (days)	Number of eggs/female (days)
15	10.800 A	35.60 A	7.500 B
20	5.861 A	25.10 A	14.286 A
25	2.725 B	22.80 A	11.500 A
30	2.350 B	17.48 A	18.000 A
35	1.800 B	11.50 B	17.830 A

Values followed by the same letters in the same column are not significantly different at P= 0.05, using Duncan's multiple range test.

Determining the minimum threshold temperature and threshold units required for the development time of mite of the false red grape mite, *T. granati*

Figures 1 (A to K) summarize the relationship between the development rate of egg and larva (active, quiescent, active+quiescent), the protonymph (active, quiescent, active+inactive), the deutonymph (active, quiescent, active+quiescent) and the development time from egg to adult when reared at different temperatures using the linear regression equation for the development rate for these instars. Figure 1-A shows the relationship between the daily development rate of the eggs and temperature, which suggest that the correlation factor (r) was 0.9760 and the threshold temperature for the development time of eggs under laboratory conditions was 6.73°C.

Whereas, the correlation factor and threshold temperature for the active larva stage was 0.9863 and 9.90°C, respectively (Figure 1-B), and for the quiescent larval stage was 0.7297 and 1.99°C (Figure 1-C), and the total development rate required for the active and quiescent larva was 0.9759 and 7.89°C, respectively (Figure 1-D).

The correlation factor and threshold temperature for the active protonymph stage was 0.9413 and 7.90°C, respectively (Figure 1-E), as for the quiescent protonymph stage was 0.977 and 7.20°C, respectively (Figure 1-F). Whereas, the total development rate required for the active and quiescent protonymph was 0.9883 and 9.38°C, respectively (Figure 1-G).

The correlation factor and threshold temperature for the active deutonymph stage was 0.7127 and 7.72°C (Figure 1-H), and for the quiescent deutonymph stage was 0.8634 and 1.90°C (Figure 1-J), the total development rate required for the active and quiescent deutonymph was 0.8049 and 6.47°C (Figure 1-I), respectively.

As for the developmental time from egg to adult, it was found that the correlation factor (r) was 0.9813 and the threshold temperature for the development time under laboratory conditions was 7.3°C (Figure 1-K), whereas Bonato *et al.* (1995) reported that the threshold temperature for the development of mite *Oligonychus gosspyii* from egg to adult was 11 °C, with a thermal range of 22-36 °C.

The accumulated heat units (Table 3) required for the developmental time of the instar of the false red grape mite *T. granati* Sayed were 153, 148.96,161.96, 140.20, and 140.40 heat units when eggs were incubated at 15, 20, 25, 30, and 35 °C, respectively. As for the larval instars at the same temperatures, the accumulated heat units for the active larvae was 54.06, 74.24, 67.95, 67.34 and 64.01 heat units, for the quiescent larval were 58.55, 50.43, 65.58, 42.72 and 62.06 heat units, and for the active + quiescent larvae were 107.36, 123.82, 125.33, 106.13 and 119.96 heat units, respectively. The accumulated heat units required for the protonymph at the same temperatures above were 68.16, 82.28, 59.85, 66.30 and 60.30 heat units for the active protonymph, 37.44, 34.56, 34.27, 39.33 and 34.75 heat units for the quiescent protonymph, and 80.93, 101.95, 84.74, 73.81 and 89.03 heat units for the active + quiescent protonymph, respectively. The accumulated heat units required for the deutonymph were 75.71, 115.74, 93.74, 105.27 and 94.80 heat units for the active deutonymph, and 68.12, 55.21, 57.17, 49.88 and 65.37 heat units for the quiescent deutonymph, and 133.07, 169.41, 133.31, 108.47 and 159.33 heat units for the active + quiescent deutonymph, respectively. The accumulated heat units required for the development of a mite from egg to adult at the same temperatures above were 462, 548.49, 500.47, 461.31 and 504.83 heat units, respectively.

Table 3. The accumulated heat units required for the development time (days) of the different stages of the grape false red mite *T. granati* (Acariformes: Tenuipalpidae) under laboratory conditions.

		Larva			Protonymph			Deutonymph			
Temp. Cº	Egg	Active	Quiescent	Active + quiescent	Active	Quiescent	Active + quiescent	Active	Quiescent	Active + quiescent	Egg to adult
15	153.0	54.0	58.5	107.3	68.1	37.4	80.9	75.7	68.1	133.0	462.0
20	148.9	74.2	50.4	123.8	82.2	34.5	101.9	115.4	55.2	169.4	548.4
25	161.9	67.9	65.5	125.3	59.8	34.2	84.7	93.74	57.1	133.3	500.4
30	140.2	67.3	42.7	106.1	66.3	39.3	73.8	105.2	49.8	108.4	461.3
35	140.4	64.0	62.0	119.9	60.3	34.7	89.0	94.80	65.3	159.3	504.8

The values in the above table represent the accumulated heat units and are calculated as follows: Accumulated heat units=(studied temperature-critical temperature) x duration of the studied stage. This value at 15ºC is 54.0 for the active larva, 58.5 for the quiescent larva and 107.3 for the active + quiescent larva. Accordingly, the third value is not necessarily the sum of the first and second values, and this apply to the whole table.

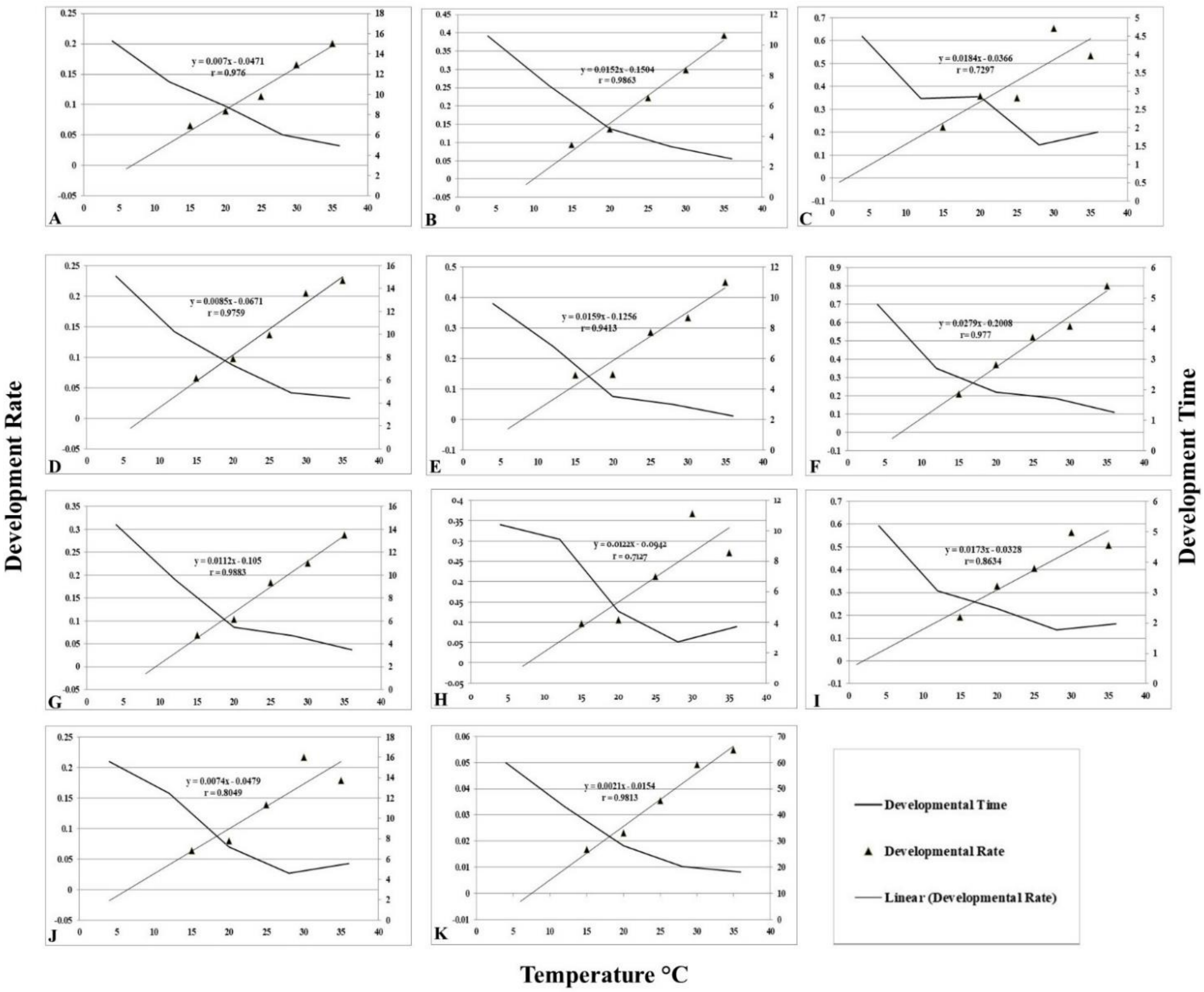

Figure 1. The relationship between the daily development rate of *T. granati* for: (A) the incubation period (egg) (B), the active larva (C), the quiescent larva (D), the larva (active and quiescent) (E), the active protonymph (F), the quiescent protonymph (G), the protonymph (active and quiescent) (H), the active deutonymph (I), the quiescent deutonymph (J), the deutonymph (active and quiescent) (K), and eggs–adults at different constant temperatures under laboratory conditions.

The results obtained confirmed the presence of a relationship between the temperatures at which this study was carried out and the rate of development necessary for the different stages of the grape false spider mite, *T. granati*. There was a difference in the accumulated heat units needed for the development of mites instar, which can be used to provide us with basic information related to the population dynamics of the mites instar of false red grapes in the field.

Such results are in agreement with previous findings (Al-Swuidy, 2003) which described the relationship between the development rate of the different stages of the old world date palm mite *Oligonychus afrasiaticus* on palm trees and different temperatures to determine the minimum development threshold of the mite stages. Based on this study, it can be concluded that the use of the thermodynamic system is essential in predicting the periodic mite population change in the field and consequently set more appropriate timing of control measures such as the release of natural enemies.

الملخص

السويدي، طه م.م. 2022. الوحدات الحرارية الكليّة الضرورية لنمو الأطوار المختلفة لحلم العنب الأحمر الكاذب *Tenuipalpus granati* Sayed تحت ظروف المختبر. مجلة وقاية النبات العربية، 40(4): 351–355. https://doi.org/10.22268/AJPP-40.4.351355

يعدّ حلم العنب الأحمر الكاذب *Tenuipalpus granati* Sayed (Acariformes: Tenuipalpidae) أحد الآفات المهمّة على أشجار العنب في العراق. هدفت هذه الدراسة إلى تحديد درجة الحرارة الحرجة وحساب الوحدات الحرارية اللازمة لتطوّر أطوار حلم العنب. نُفذّت الدراسة تحت ظروف المختبر، وذلك بتربية أطوار الحلم

المختلفة على السطح السفلي لأوراق العنب المزروعة حديثاً تحت درجات حرارة مختلفة (10، 15، 20، 25، 30، 35 و 40±2°س)، ورطوبة نسبية (50−60±5%)، وفترة ضوئية 16:8 ساعات (ضوء:ظلام). أظهرت النتائج أن مدّة تطوّر البيضة، اليرقة، الدور الحوري الأول protonymph، والدور الحوري الثاني deutonymph (نشط، ساكن، نشط + ساكن)، عند درجات حرارة 10، 15، 20، 25، 30، 35 و40°س، قلّت تدريجياً مع زيادة درجة الحرارة. علاوةً على ذلك، كانت مدّة تطوّر حضانة البيض 15.3 و 4.98 يوماً، واليرقة (نشطة + ساكنة) 15.1 و4.43 يوماً، والطور الحوري الأول (نشط + ساكن) 14.4 و 3.48 يوماً، الطور الحوري الثاني (نشط +ساكن) 15.6 و 5.58 يوماً عند درجتي الحرارة 15 و35°س، على التوالي. بالإضافة إلى ذلك، كان وقت التطور من البيض حتى البالغة 60.00 و18.26 يوماً عند درجتي الحرارة 15 و 35°س، على التوالي. وكذلك كانت درجة الحرارة الحرجة 6.73، 7.89، 9.38، 6.47 و 7.3°س، على التوالي. واختلفت كمية الوحدات الحرارية التراكمية المطلوبة لتطوّر أطوار حلم العنب الاحمر الكاذب باختلاف درجة الحرارة الحرجة ومدة التطور، ولم نحصل على أيّ نتائج مهمة عند درجتي الحرارة 10 و40°س.

كلمات مفتاحية: الحلم الأحمر الكاذب، الوحدات الحرارية، *Tenuipalpus granai*، معدّل التطوّر.

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