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Effect of temperature on the development of *Tetranychus urticae* and *Eotetranychus lewisi* on strawberry

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Abstract
The effect of different temperatures on the development of *Tetranychus urticae* Koch and *Eotetranychus lewisi* (McGregor) on strawberry was studied in the laboratory of Department of Entomology, University of California, Davis, USA in 2012. The study results revealed that the immature development of both the mites on strawberry was faster at 20 (6.67 to 7.33 days) and 25 °C (3.33 to 3.67 days) as compared to 15 °C (11.66 to 13.33 days). The total time taken for the development of *T. urticae* and *E. lewisi* was found to be decreased with increase in temperature. The maximum fecundity of both the mites was observed at 25 °C. The fecundity of *T. urticae* (49.15 eggs/female) was found to be more on strawberry as compared to *E. lewisi* (41.25 eggs/female). Therefore, strawberry was found to be more suitable host for *T. urticae*. Although, *E. lewisi* develops faster at lowest temperature (30.00 days) as compared to *T. urticae* (35.40 days) and successfully completes its life cycle on strawberry at all temperatures. Thus, *E. lewisi* can become a major pest of strawberry in near future along with *T. urticae*. Our results showed that temperature is a portentous component that can affect the development and reproduction of both the mites on strawberry.

Keywords: Biology, *Eotetranychus lewisi*, Strawberry, Temperature, *Tetranychus urticae*

1. Introduction
The two-spotted spider mite, *Tetranychus urticae* Koch (Acari : Tetranychidae) has a wide host range throughout the world. It is serious pest of many horticultural crops. Among horticultural crops, its favourable host is strawberry [1]. Infestation due to *T. urticae* can cause reduction in crop yield as well as aesthetic injuries, because of webbing produced by the mites. The piercing and removal of cell contents from strawberry leaves by spider mites results in loss of chlorophyll and reduced photosynthetic rates, leaving the leaf with white or yellow spots, a condition termed as "stippling" [2]. At the high population on the host, it can suppress flower and leaf development and ultimately affect the yield and quality of fruits produced [3]. Thus, two-spotted spider mite is a major target for integrated pest management (IPM) programmes in strawberry production [4].

Lewis spider mite or Lewis mite, *Eotetranychus lewisi* (McGregor) is a pest of many host plants. In the US, it has been reported on citrus and greenhouse poinsettias. Lewis mites have been seen on strawberries and raspberries, but growers appear to be noticing increased infestations in the recent years. The infestation by *E. lewisi* on strawberry was reported from Philippines [5]. Both the mites look similar in their general appearance. But, comparing adult females, Lewis mites are smaller than two-spotted spider mite and have several small spots on their body while two-spotted spider mite have a single dark spot on either side of the body. Damage to strawberry by *E. lewisi* is similar to that of the *T. urticae*. Recently, *E. lewisi* outbreaks have caused significant damage to strawberry fields, particularly organic production, thereby becoming a problematic pest of commercially cultivated strawberries [6].

Therefore, management is a great concern in lowering the population of both the tetranychid mites on strawberry below the economic threshold levels. For this, the healthy approach is to adopt IPM for their management. The principle of IPM depends on the economic value of insect pest on a particular host for their implementation. The development and population densities of mites are very sensitive to weather conditions. Out of all weather parameters, temperature is an important abiotic factor which has direct relation with the pest population levels in means of mite growth, survivorship and fecundity of mites. [7-9] Therefore, weather factors should be considered when developing pest management programs for spider mites.

Many authors studied the effect of temperature on the development of tetranychid mites on different host plants, such as *T. urticae* on cotton, [10] *Tetranychus piercei* McGregor on banana, [11] *Tetranychus truncates* Ehara on mulberry, [12] *Eutetranychus banksi* (McGregor) on sweet orange, [13] *T. urticae* on beans, [14] *T. urticae* on apple, [15] *T. turkestani* Ugarov and Nikolski on eggplant, [16], *Amphitetranychus viennensis* (Zacher), [17] *T. turkestani* on bean, [18] *T. urticae* on egg plant, [19] *E. orientalis* (Klein) on Siris, [20] *T. turkestani* on cucumber, [21] and *Tetranycopsis horridus* (Canestrini and Fanzago) on hazelnut. [22] A literature review revealed that there is lack of information available on the biology of *T. urticae* and *E. lewisi* on strawberry at different temperatures. Therefore, the current study was conducted to investigate the effect of temperature on the biology of *T. urticae* and *E. lewisi* on strawberry under laboratory conditions.

2. Material and Methods

2.1 Mites and Experimental Arena

The pure culture of *T. urticae and E. lewisi* were propagated in the laboratory of Department of Entomology, University of California, Davis, USA. The present study was conducted in 2012 in the months from September to October. All strawberry leaves used for experiments were collected from organic field and placed in water containing a drop of dish detergent, rinsed several times with water, and examined under a stereozoom microscope to assure that no other mites were present. For the experiment, leaves were cut and placed on water saturated filter paper (Whatman™ - 90 mm) in Petri dishes. The leaves were changed as often as needed to provide adequate forage for each mite species.

2.2 Developmental studies of *Tetranychus urticae* and *Eotetranychus lewisi* on strawberry

The detail biology of both the mite species on strawberry was studied at 15, 20 and 25 °C temperatures. Leaf-disc technique earlier used for biological studies was used for the present studies [23]. Leaf-discs were cut and placed on water saturated filter paper (Whatman™ - 90 mm) in Petri dishes. For recording the incubation period, 10 gravid females of *T. urticae* and *E. lewisi* were released on strawberry leaves separately to obtain sufficient number of eggs. After 24 hours of release, females were removed and eggs were subsequently observed daily for their hatching. Number of eggs hatched at different intervals was counted for calculating the average incubation period. For studying different parameters of development of both the mites, one newly emerged larva per leaf-disc was released on strawberry. The Petri dishes containing leaf-discs were kept in incubators at 15, 20 and 25 °C. The observations regarding incubation, larval, nympal and larval + nymphal periods were recorded daily. Observations regarding longevity and fecundity were also recorded daily until the death of the female adult.

2.3 Statistical Analysis

The recorded data was subjected to analysis of variance (ANOVA) using Completely Randomized Design (CRD) and the mean values obtained for developmental parameters on strawberry at three temperatures were compared.

3.0 Results and Discussion

3.1 Development of *T. urticae* on strawberry at 15, 20 and 25 °C

The incubation period of *T. urticae* on strawberry increased with decreasing temperature. At 15 °C temperature, the egg stage was found to be 11.66 days which is significantly more as compared to 20 and 25 °C. After hatching, the time for larval period was significantly more as compared to 20 and 25 °C. The larval period was found to be significantly similar at 20 and 25 °C. The longest stage in the development was the nymphal period which was found at lowest temperature as compared to others. The immature development was found to be significantly faster at 20 and 25 as compared to 15 °C (Table 1). The lowest time for longevity of *T. urticae* was at 15 followed by 25 and 20 °C. The data indicate that the total time taken for the development of *T. urticae* decreased with increasing temperature. The maximum number of eggs laid by adult female of *T. urticae* was found to be at 25 followed by 20 and 15 °C (Table 2).

3.2 Development of *E. lewisi* on strawberry at 15, 20 and 25 °C

The eggs of *E. lewisi* were hatched after 13.33, 6.67 and 3.33 days at 15, 20 and 25 °C, respectively on strawberry leaves. The larval period was found to be significantly more at 15 as compared to 25 °C which is at par with 20 °C. The longest nymphal period was at 15 followed by 20 and 25 °C. Thus, the immature development was significantly shorter at 25 °C as compared to other two temperatures (Table 3). The longevity of *E. lewisi* was found to be in range from 10.60 to 12.10 days. The longevity was statistically at par at all temperatures. The developmental period of *E. lewisi* decreased with increasing temperature and found to be lower at 25 °C. The total eggs laid by mite wasfound to be maximum at 25 (41.25 eggs/mite) followed by 20 (28.30 eggs/mite) and 15 °C (9.60 eggs/mite) (Table 4).

The life cycle of *E. lewisi* was completed in 30.00 days at 15 °C but *T. urticae* required more time (35.40 days) to complete its development at same temperature. The longevity of *E. lewisi* was also more as compared to *T. urticae* at lowest temperature. But fecundity was in contrast to longevity as it was more in case of *T. urticae* at all temperatures. Thus, strawberry found to be more suitable host for *T. urticae*. Although, *E. lewisi* develops faster at lowest temperature as compared to *T. urticae* and successfully completed its life cycle on strawberry. Therefore, *E. lewisi* can become a major pest of strawberry in near future along with *T. urticae*. Out of three temperatures, 25 °C found to be more favourable in context to faster development and more fecundity of both the mites on strawberry. Bounfour and Tanigoshi studied the effect of temperature on the development of *T. urticae* and *Eotetranychus carpini borealis* Ewing on raspberry. They found that the time taken for the development of *T. urticae* and *E. carpini borealis* was shorter on increase of temperature. The larval period of *T. urticae* was shorter than *E. carpini borealis* at all temperatures. The immature development of *T. urticae* was shorter as compared to *E. carpini borealis,* which is comparable to our study because at 20 and 25 °C, both the mites completed their immature stages faster as compared to lowest temperature. The data given in Table 1 and 3 indicate that *T. urticae* develops faster than *E. lewisi* at 20 and 25 °C in contrast to 15 °C. These results corroborate with the studies conducted by Bounfour and Tanigoshi. They found that *E. carpini borealis* developed faster at lower temperatures than *T. urticae*. They concluded that the longevity of *E. carpini borealis* was similar at all temperatures which are again similar with our studies [8]. The range of temperature threshold of *E. lewisi* was observed

between 9.0 to 28.2 °C for its development. The incubation period was found to be 2.5 days, while larval, protonymphal and deutonymphal stages took 1.8, 1.4 and 2.3 days, respectively at 26 °C. The fecundity reported was 21, 51 and 32 eggs at 20, 24 and 28 °C, respectively. The longevity of female was 12.0, 16.0 and 9.6 days at 20, 24 and 28 °C, respectively. [24] The total development of *T. urticae* was completed in 13.75 days at 25 °C [25] which is very near to our results (15.80 days in Table 1). The decreased developmental time reported in our study for both the mites are comparable to those reported for *T. urticae* at different temperatures by other authors. [26] The temperature affected all the developmental stages of *T. urticae* and *Panonychus ulmi* Koch on apple. [27] The findings indicate that with the increase in temperature, the time taken for the development of both the mites was decreased.

Table 1: Development of immature stages of *T. urticae* on strawberry at 15, 20 and 25 °C.

Temperatures (°C)	Development of immature stages (days)			
	Incubation period	Larval period	Nymphal period	Larval + Nymphal period
15	11.66 (3.55)	7.80 (2.96)	19.10 (4.48)	26.90 (5.28)
20	7.33 (2.88)	3.10 (2.02)	3.60 (2.14)	6.70 (2.77)
25	3.67 (2.15)	2.30 (1.81)	2.10 (1.76)	4.40 (2.32)
CD (0.05%)	(0.27)	(0.74)	(0.83)	(0.89)

Table 2: Longevity, fecundity and total developmental period of *T. urticae* on strawberry at 15, 20 and 25 °C.

Temperatures (°C)	Longevity (days)	Fecundity (no. of eggs)	Total developmental period (days)
15	8.50 (3.07)	11.80 (3.56)	35.40 (6.03)
20	13.60 (3.82)	39.70 (6.38)	20.30 (4.61)
25	11.40 (3.52)	49.15 (7.07)	15.80 (4.09)
CD (0.05%)	(0.12)	(0.19)	(0.97)

Table 3: Development of immature stages of *E. lewisi* on strawberry at 15, 20 and 25 °C.

Temperatures (°C)	Development of immature stages (days)			
	Incubation period	Larval period	Nymphal period	Larval + Nymphal period
15	13.33 (3.78)	7.45 (2.90)	11.95 (3.58)	19.40 (4.51)
20	6.67 (2.76)	4.55 (2.35)	4.45 (2.33)	9.00 (3.16)
25	3.33 (2.08)	3.60 (2.14)	3.65 (2.15)	7.25 (2.87)
CD (0.05%)	(0.30)	(0.67)	(0.13)	(0.11)

Table 4: Longevity, fecundity and total developmental period of *E. lewisi* on strawberry at 15, 20 and 25 °C.

Temperatures (°C)	Longevity (days)	Fecundity (no. of eggs)	Total developmental period (days)
15	10.60 (3.40)	9.60 (3.25)	30.00 (5.56)
20	14.10 (3.88)	28.30 (5.37)	23.10 (4.90)
25	12.10 (3.62)	41.25 (6.49)	19.35 (4.51)
CD (0.05%)	(0.99)	(0.27)	(0.11)

4. Conclusion

The time of development of both the mite species on strawberry was decreased at high temperatures as compared to low. Thus, the results of our study showed that temperature is a portentous component that can affect the development and reproduction of both the mites on strawberry. *E. lewisi* can become a pest of strawberry along with *T. urticae* in near future.

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