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Original Research Paper

Temperature dependent survival and developmental biology of the spider mite, *Tetranychus puschelii* Meyer (Acari: Tetranychidae) on selected host crops

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ABSTRACT

The study on the survival of the spider mite, *Tetranychus puschelii* Meyer on selected seven host plants *viz.*, papaya (*Carica papaya* L.), sunflower (*Helianthus annuus* L.), cucumber (*Cucumis maderaspatanus* L.), okra (*Abelmoschus esculentus* (L.) Moench), brinjal (*Solanum melongena* L.), jasmine (*Jasminum sambac* (L.) Aiton) and *dahlia* at seven different constant temperatures (16±1º, 20±1º, 24±1º, 28±1º, 32±1º, 36±1º and 40ºC) and the developmental biology on two selected hosts at five different constant temperatures (20±1º, 24±1º, 28±1º, 32±1º and 36±1ºC), were carried out. On cucumber and papaya, the per cent egg hatching and larval survivability was 100%, whereas, the survivability was 99.18% & 96.96% in protonymph and 100% & 92.18% in the deutonymphal stages, respectively. Cucumber (99.18%) and papaya (84.09%) recorded more than 80% mite survival from egg to adult stages. So, these two hosts were further used to study the survival of the mites at five different constant temperatures. The optimal growth of *T. puschelii* on cucumber was at the temperature range of 20±1º to 32±1ºC, while, on papaya the optimal development of *T. puschelii* was between 24±1º to 32±1ºC. The results of the developmental biology on cucumber and papaya showed that the time taken by *T. puschelii* from egg to adult decreased as the temperature increased from 20ºC to 32ºC and development was found to be nil at 36ºC as it was extremely higher temperature compared to other temperature conditions.

Keywords: Biology, survivability, temperature, *Tetranychus puschelii*

INTRODUCTION

The spider mites are members of the family Tetranychidae belong to the suborder Prostigmata and include 1345 described species under 89 genera (www1.montpellier.inrae.fr/CBGP/spmweb). The spider mites are cosmopolitan in distribution, exclusively herbivorous, known to spend their complete life on plants and can spin fine strands of protective webbings on the host plants. They cause damage to the crops by puncturing the plant cells and feeding on the sap contents. The spider mite, *Tetranychus puschelii* Meyer (Acari: Tetranychidae) is distributed all over the Oriental (Asia) and Afrotropical (Africa) regions. It was first reported in Africa by Meyer (1974) on *Cephalocroton mollis* Klotzsch and *Sida chrysantha* Ulbr. (Meyer). In India, it was first reported in Assam by Sadana & Gupta (1983) on an unidentified host plant and thereafter Zeity et al. (2017) on brinjal, *Solanum melongena* L. and *Capsicum annuum* L. in different locations of India.

Understanding the biology and feeding behaviour of any phytophagous mite is a pre requisite in any pest management strategy. Hence, knowing the factors that affect the development of phytophagous mite pests is more essential. Factors such as temperature, humidity, light, host plants and biochemical composition crucially affect the normal growth and development of mite pests. Among these, the temperature plays a key role in the survival, development and reproduction of any mite pest. Thermal optimum is the temperature at which a species develops, reproduces and survives, whereas a temperature lower or higher than the optimum results in a negative developmental rate. Temperature influences the entire life cycle of a mite *i.e.* the duration of every stage and the total number of immatures reaching the adult stage. Therefore, knowing the temperature requirements of the life stages of a target pest species is important to understand its potential distribution and population dynamics. The capability of a pest to develop under different temperature conditions determines its survival under different climatic conditions, which is important in pest outbreaks. The results of the studies of insect and non-insect pests at constant temperatures can be used to forecast their seasonal and phenological development, population dynamics and management strategies (Du Plessis et al., 2020).

In addition to temperature, factors related to host plants such as nutritional value, biochemical aspects like primary and secondary metabolites, surface texture, leaf toughness, the waxy surface on the leaf, taste/odour compounds of the leaves, pubescence (density and type of hairs), spines, glandular secretions facilitate the insects and mites to accept or reject the host which further helps to determine the insect survivorship. In the same way the spider mite's life history parameters (growth, development, reproductive capability and population growth) are also directly influenced by the host plants.

MATERIALS AND METHODS

The present study on the survival of the spider mite, *T. puschelii* on selected seven host plants *viz.*, papaya (*Carica papaya* L.), sunflower (*Helianthus annuus* L.), cucumber (*Cucumis maderaspatanus* L.), okra (*Abelmoschus esculentus* (L.) Moench), brinjal (*Solanum melongena* L.), jasmine (*Jasminum sambac* (L.) Aiton) and Dahlia at seven different constant temperatures (16±1º, 20±1º, 24±1º, 28±1º, 32±1º, 36±1º and 40ºC) and the developmental biology of *T. puschelii* on two selected hosts (cucumber and papaya) at five different constant temperatures (20±1º, 24±1º, 28±1º, 32±1º and 36±1ºC) were carried out at the Acarology Unit of the Department of Agricultural Entomology, University of Agricultural Sciences, Bangalore, India, during 2022 to 2023, with facilities of the All India Network Project (AINP) on Agricultural Acarology. These hosts were selected based on the review of literature and the availability.

Mass rearing of the spider mite, *T. puschelii* in the laboratory

The pure culture of the spider mite, *T. puschelii* maintained in the laboratory of AINP on Agricultural Acarology, University of Agricultural Sciences, Bangalore, India, was obtained for further raising of the culture required for the experimental studies. Microscopic slides of the male and female mites were prepared and identification was confirmed using taxonomic keys given by Gupta & Gupta (1994), Seeman & Beard (2011) and Srinivasa et al. (2021) (Fig. 1).

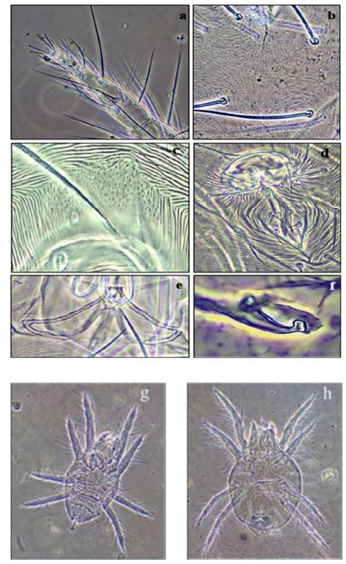

Fig. 1 : Identification characteristics of *Tetranychus puschelii* and adult male and female of *T. puschelii*

a. Tarsus I of female; Plate b. dorsal striae between *e1* & *f1* forming diamond shape; Plate c. Pregenital area with longitudinal broken lines; Plate d. Genital area of female; Plate e. Peritreme; Plate f. Adeagus; Plate g. Male and Plate h. Female

Female: The body is carmine in colour, with long and slender dorsal body setae, tarsus I with 4 tactile setae proximad to proximal duplex setae and one solenidion present lateral between duplex setal pairs (Plate 1a), the dorsal striae longitudinal between dorsocentral setae *e1* and *f1* form a diamond-shaped pattern and the dorsal lobes on the striae small, narrow, triangular and separated by space at their bases (Plate 1b). Striae on the pregenital area is longitudinal with broken lines (Plate 1c) and wavy-like striae surrounding the genital area (Plate 1d). Peritreme hooked distally (Plate 1e).

Male: The male is smaller than the female and lighter in colour. The shaft of the aedeagus is short and curved slightly dorsad forming a berry-shapped knob as in *Tetranychus neocaledonicus* Andre but with a short neck (Plate 1f).

After confirming the species, fifty teliochrysalis stage females (quiescent deutonymph) along with an equal number of males were randomly picked from the laboratory culture and transferred onto a separate 2.5 x 2.5 cm mulberry leaf bits placed abaxial side up on the wet sponge placed in 9″×6″ plastic tray and allowed for colonization (for at least 12 to 15 days). Representative male from each leaf bit was picked and confirmed once again for the purity of culture. Later, mite colonies of different leaf bits were pooled and used as a pure culture. The excised mulberry leaf bits were changed every 7-8 day or as and when necessary. The water was maintained in the tray daily to keep the sponge pads in wet condition to maintain the freshness of the mulberry leaves. The culture was maintained in the laboratory for the entire experimentation period and used for further studies on selected host plants following the excised leaf disc technique.

Testing the survival of *T. puschelii* under different constant temperature regimes

Survival studies were conducted in the laboratory for *T. puschelii* on seven different host plants *viz*., brinjal, cucumber, dahlia, jasmine, okra, sunflower and papaya which were selected based on the previous reports as hosts (Meyer, 1974; Bolland et al., 1998; Zeity et al., 2017) at room temperature of 28±1ºC. Twenty-five female mites were released on the respective host plant leaf discs and observations were recorded for every 24 hours of all the life stages of the mite (number of eggs laid per day, longevity and mortality). The best two host plants recording more than 80% mite survival were selected for further detailed studies. About 40-50 gravid female mites were released on 5 cm x 5 cm respective two different host leaf bits kept on wet sponge in 9″x6″ diameter plastic tray and allowed for egg laying at seven different constant temperatures (16±1°, 20±°, 24±1°, 28±1°, 32±1°, 36±1° and 40±1°C) with the photoperiod of 14:10 (L:D) h condition separately in a BOD incubator. The leaf bits were observed periodically (every 6 hours) under a stereo-binocular microscope until the number of eggs laid was approximately one hundred at each temperature condition. Later, the females were removed from the leaf bits and the eggs were further observed periodically for hatching. Temperature-wise data was recorded as the number survived at each stage of development (larva, protonymph, deutonymph) and the survival from egg to adult was computed and expressed in percentage. The survival data for each stage of development *i.e.* egg hatchability, larva, protonymph, deutonymph and total development from egg to adult across different temperature conditions was compared across two host plants.

Developmental biology of *T. puschelii* on selected host plants at different temperatures

Temperature-dependent development of the spider mite, *T. puschelii* was studied on two different hosts *viz*., cucumber and papaya at five different constant temperatures *viz*., 20±1ºC; 75-80% relative humidity (RH), 24±1ºC; 70-75% RH, 28±1ºC; 65-70% RH, 32±1ºC; 60-65% RH, 36°±1C; 55-60% RH with the photoperiod of 14:10 (L:D) h conditions separately in a BOD incubator. Disease free, mature and thick green leaves of the two host plants (cucumber and papaya) were collected from the field and were brushed thoroughly. The leaves were further examined under a stereo zoom microscope to check the presence of any associated mites and predators, if any, were removed from the leaf. The leaves were then cut into bits of 5 cm x 5 cm and were placed on the wet sponge in 9″x6″ plastic tray. A cohort of 25 to 30 gravid female mites were picked from the pure laboratory culture and released on to excised leaf discs of selected hosts and were allowed to lay eggs at different temperature conditions in separate incubators. After obtaining a sufficient number of eggs, the females were removed from the leaf discs and eggs were further observed periodically for hatching. Soon after hatching, the larvae were individually transferred using a fine camel brush to 50 different 1.5 cm x 1.5 cm fresh leaf discs that kept the abaxial side up on wet foam in 9″x6″ plastic trays. 50 leaf bits of the respective hosts were maintained. The trays were placed in the incubator with set temperatures (20±1ºC; 75-80% RH, 24±1ºC; 70-75% RH, 28±1ºC; 65-70% RH, 32±1ºC; 60-65% RH, 36°±1C; 55-60% RH). Further, the development of individual mites was observed for every 6-hour interval under a stereo zoom microscope till they developed into adults. The immature stages during their development were carefully transferred to new leaf bits as and when necessary. The trays were watered daily to keep the foams in wet condition to maintain the freshness of the leaf bits. The time taken to pass through different stages *viz*., larvae, quiescent 1 (larvochrysalis), protonymphs, quiescent 2 (nymphochrysalis), deutonymphs, quiescent 3 (teliochrysalis) and adults was computed.

Data in respect of the duration of different developmental stages were expressed as mean±SE. The data concerning complete development from egg to adult were analyzed for male and female mites separately following One-way ANOVA using statistical software SPSS 23 and the means were compared at 5% level of probability.

Table 1 : Per cent survival of *Tetranychus puschelii* on different host plants at room temperature (28±1ºC)

Host plant	Survivability (%)				
	Egg	Larva	Protonymph	Deutonymph	Egg to adult
Papaya	100.00	100.00	96.96	92.18	84.09
Sunflower	88.00	100.00	100.00	86.36	72.00
Brinjal	88.23	98.90	62.22	91.07	48.03
Okra	87.61	98.91	78.02	91.54	49.52
Cucumber	100.00	100.00	99.18	100.00	99.18
Dhalia	66.03	37.14	0.23	-	-
Jasmine	83.30	42.85	-	-	-

RESULTS AND DISCUSSION

Survivability of *T. puschelii* at room temperature (28±1ºC) under laboratory conditions

The spider mites undergo eight life stages *i.e.* egg, larva, quiescent 1 (larvochrysalis) protonymph, quiescent 2 (nymphochrysalis), deutonymph, quiescent 3 (teliochrysalis) and the adult. The eggs and the quiescent stages are inactive stages whereas, the rest of the life stages are active stages. The survival at room temperature was evident from the completion of the life cycle from egg to adult on five host plants (brinjal, cucumber, okra, sunflower and papaya), whereas, jasmine and dhalia leaves did not support the mite's development (Table 1). Among all the seven hosts used, the lowest percentage of egg hatching was recorded on *Dahlia* (66.03%) and more than 80% on all the other six hosts (Table 1).

Dahlia and jasmine did not support further mite development and the released adults & hatched larvae walked out of the leaves. Hence, jasmine and dahlia were considered as unsuitable hosts for *T. puschelii* under the laboratory condition. On sunflower and okra leaf, the egg hatchability was 88.00 and 87.61 per cent, while the larval survivability was 100 and 98.91%, respectively. Per cent mortality in the protonymphal and deutonymphal stage was higher on okra leaf (78.02% and 91.54% survivability) compared to sunflower (100% and 86.36%). Further, the survivability at the adult stage was 72.00 and 49.52% on sunflower and okra leaves, respectively. The problem with sunflower and okra leaves was that the leaves curled up and lost contact with the wet cotton sponge making the mites get trapped on the wet sponge. Hence, sunflower and okra leaves were also considered unsuitable hosts for laboratory rearing. Further, the brinjal leaves were found to deteriorate within a period of 3 to 4 days, while the egg hatchability and larval survivability were 88.23% and 98.90%, respectively. The nymphal stages recorded maximum mortality and the number survived were 62.22% and 91.07%, respectively at the protonymph and deutonymphal stages and 48.03% of mite's survival was recorded at the adult stage. Brinjal leaf was also considered an unsuitable laboratory host for *T. puschelii*.

On cucumber and papaya, the per cent egg hatching and larval survivability was 100%, whereas, the survivability was 99.18% & 96.96% in protonymph and 100% & 92.18% in the deutonymphal stages, respectively. Cucumber (99.18%) and papaya (84.09%) recorded more than 80% mite survival from egg to adult stages. So, these two hosts were further used to study the survivability of the mites at seven different constant temperatures (16±1°, 20±°, 24±1°, 28±1°, 32±1°, 36±1° and 40±1°C) with the photoperiod of 14:10 (L:D) h condition separately in a BOD incubator. The work on the survivability of *T. puschelii* on different hosts is the first of its kind. However, the work on the other Tetranychidae species is taken into consideration for comparison. As per the report of Shivakumar (2021), the overall survivability of *Tetranychus fijiensis* Hirst on citrus (20-30°C) ranged from 41.17 to 64.00%, while, on papaya it ranged from 47.52 to 73.00%. Thus, papaya was favorable host for *T. fijiensis*. Similarly, the overall survival of *Oligonychus biharensis* (Hirst) on *Cassia fistula* L. at 20-32 °C ranged from 44 to 86%, while on Cassava it ranged from19 to 87%. Further, for *Oligonychus tylus* Baker & Pritchard banana was a more preferred host compared to maize.

Table 2 : Effect of different constant temperature conditions on the survival of *Tetranychus puschelii* on cucumber in the laboratory

Temperature conditions (ºC; RH%)	Per cent survivability				
	Egg	Larva	Protonymph	Deutonymph	Egg to adult
16; 80-85	0	-	-	-	-
20; 75-80	98.31	99.14	100	73.27	67.22
24; 70-75	63.39	98.59	95.71	94.02	53.57
28; 65-70	99.75	99.14	100	98.22	99.03
32; 60-65	100	100	61.68	95.45	58.87
36; 55-60	8.73	-	-	-	-
40; 50-55	10.37	-	-	-	-

Effect of different constant temperature conditions on the survival of *T. puschelii* on cucumber

The findings revealed the distinct trends in egg hatchability, larval survival, nymphal survival and overall egg-to-adult survival (Table 2). At 28ºC on cucumber, the percentage of egg hatching and larval survival was 99.75% and 99.14%, respectively. The survival at the nymphal stages ranged from 98 to 100% and the total survivability from egg to adult was 99.03% which was highest compared to other temperatures. At 24ºC and 20ºC the total egg to adult survival was 53.57% and 67.22%, respectively (Table 2) and as the temperature dropped, the development was potentially slowed down due to increased vulnerability. At 32ºC the egg hatchability and larval survivability was 100% and at the nymphal stages, the survival ranged from 61.68% to 95.45%. The total egg to adult survivability was 58.87% *i.e.* the survivability percentage decreased with an increase in temperature. At an extremely low temperature of 16ºC, the eggs remained unhatched and at extremely high temperatures (36º and 40ºC) the majority of the eggs were observed to shrink and later the hatched larvae couldn't survive for a longer time. The overall survivability of *T. puschelii* on cucumber from egg to adult stage ranged from 53.57% to 99.03%. Praslicka & Huszar (2004) on *T. urticae* (cucumber), Moro et al. (2012) on *T. urticae* (papaya) and Win et al. (2018) on *T. truncatus* (mulberry), reported that the developmental duration of mites decreased at higher temperatures and longer developmental duration was observed at lower temperature within a certain temperature range (20ºC to 35ºC). The variations in the developmental duration could be due to the effect of different hosts and different species of *Tetranychus.*

Effect of different constant temperature conditions on the survival of *T. puschelii* on papaya

The temperature had an evident effect on the survivability of *T. puschelii* on papaya. At 28ºC, the egg hatchability and larval survivability were 99.02% and 97.07%, respectively (Table 3). At both the nymphal stages, survival was 96% and the per cent survival from egg to adult stage was 84.02% which was considerably higher compared to all other temperatures, thus the temperature of 28ºC notably seemed to be the most favourable. While at 24ºC the per cent egg hatchability was 94.33% and 80% larval survivability was recorded. At nymphal stages, the survivability was 98.75% at protonymph and 83.54% at the deutonymphal stage whereas, the total egg-to-adult survival was 58.49%. The cumulative egg-to-adult survival at 32ºC was 52.03% and it was observed that increased temperature simultaneously decreased the survivability percentage. In contrast, at extremely low temperatures of 16º and 20ºC, the egg hatchability was 63.24% and 100%, respectively. The larval survivability was 100% at both temperatures whereas, the maximum mortality was recorded at the nymphal stages and the total egg to adult survival was 12.82% and 15.38%. As compared to the lower temperatures on cucumber, the papaya leaves supported the mite to complete the life cycle. At the extreme higher temperatures of 36º and 40ºC, the results were as same as on cucumber. Similar results were observed on papaya for *Tetranychus fijiensis*, the maximum survival per cent was 73% and 70.58% at the temperatures 24º and 28ºC, respectively (Shivakumar, 2021).

Table 3 : Effect of different constant temperature conditions on survival of *Tetranychus puschelii* on papaya in the laboratory

Temperature conditions (ºC; RH%)	Per cent survivability				
	Egg	Larva	Protonymph	Deutonymph	Egg to adult
16; 80-85	63.24	100	79.72	61.01	12.82
20; 75-80	100	100	86.53	25.55	15.38
24; 70-75	94.33	80.00	98.75	83.54	58.49
28; 65-70	99.02	97.07	96.07	96.93	84.02
32; 60-65	80.48	81.29	89.89	97.75	52.03
36; 55-60	12.5	0.00	-	-	-
40; 50-55	3.47	0.00	-	-	-

Comparative developmental biology of *T. puschelii* on two selected host plants at five constant temperatures and relative humidity

The developmental duration of eight life stages of *Tetranychus puschelii* was recorded on two selected host plants *i.e.* cucumber and papaya at five different constant temperatures (20±°C, 24±1°C, 28±1°C, 32±1°C and 36±1°C) with the photoperiod of 14:10 (L:D) h conditions (Table 4 & 5; Fig. 2).

The developmental duration between females and males of *T. puschelii* on different hosts and temperatures were found to be significantly different (Fig. 2) and the comparison between females and males across different hosts and temperatures is presented in Tables 4 & 5. The female mites at 20±1ºC took 26.69 and 24.88 days to complete the total development from egg to adult on cucumber and papaya, respectively. Whereas, at 24±1ºC the female mites took 15.26 and 14.57 days to complete the development on cucumber and papaya, respectively (Table 4 & 5; Fig. 2).

The total time taken to develop from egg to adult stage at 28±1ºC was 14.97 days on cucumber and 16.10 days on papaya, correspondingly at 32±1ºC it was 11.83 and 11.32 days on cucumber and papaya, respectively. Males took less time for total development from egg to adult compared to females. At 20±1ºC males took 25.58 days on cucumber and 23.52 days on papaya for total development. At 24±1ºC 14.08 and 13.31 days on cucumber and papaya, respectively. The male mite at 28±1ºC took 13.28 and 14.33 days for total development; at 32±1ºC, 9.41 and 10.12 days on cucumber and papaya, respectively.

The developmental biology data of *T. puschelii* at 36±1ºC temperature and 55-60% relative humidity did not support the development of the mites on the two hosts *i.e.* cucumber and papaya. The required number of eggs for the study were laid by the gravid females on all the host leaf bits in a very short period of time compared to other above-mentioned temperature conditions but the eggs laid were found to be shrinked and remained unhatched (Fig. 3). This could be due to high temperature caused by the temperature stress which affected adversely on the development of an egg to a viable offspring and this unfavourable condition made the eggs loose viability and shrink and remain unhatched.

The results of the present study showed that the developmental time taken by *T. puschelii* decreased as the temperature increased from 20ºC to 32ºC and development was found to be nil at 36ºC as it was an extremely higher temperature compared to other temperature conditions.

According to the findings of Fu et al. (2002) with *T. piercei* on banana leaves, the total time taken for development from egg to adult was 33.5, 34.5, 21.8, 16.1, 12.4, 8.2 days for females and 32.0, 15.9, 11.4, 8.0, 7.3 and 7.0 days for males at 16º, 20º, 24º, 28º, 32º and 36ºC temperature conditions, respectively. Praslicka & Huszar (2004) on *T. urticae* (cucumber), Moro et al. (2012) on *T. urticae* (papaya) and Win et al. (2018) on *T. truncatus* (mulberry), reported that the developmental duration of mites decreased at higher temperatures and longer developmental duration was observed at lower temperature within a certain temperature range (20ºC to 35ºC). The variations in the developmental duration could be due to the effect

Table 4 : Developmental biology of *Tetranychus puschelii* at four constant temperature and relative humidity on cucumber

Developmental stages	Mean duration of development on cucumber (h)							
	20±1ºC & 75-80%		24±1ºC & 70-75%		28±1ºC & 65-70%		32±1ºC & 60-65%	
	Female (n=43)	Male (n=3)	Female (n=40)	Male (n=3)	Female (n=42)	Male (n=5)	Female (n=38)	Male (n=3)
Egg	264.00±0.00	264.00±0.00	96.00±0.00	96.00±0.00	68.00±0.00	68.00±0.00	52.00±0.00	52.00±0.00
Larva	43.11±1.09	46.00±2.00	45.15±1.05	46.00±2.00	45.28±0.98	43.20±4.80	34.57±1.60	28.00±4.00
Quiescent I	30.69±1.15	34.00±7.21	48.00±1.56	42.00±3.46	38.57±1.02	33.60±2.40	44.36±1.09	32.00±2.00
Protonymph	123.90±2.67	120.00±10.39	66.15±2.48	46.00±4.00	84.85±2.11	70.80±3.97	41.05±1.12	34.00±5.29
Quiescent II	59.02±1.71	58.00±5.29	37.95±0.94	42.00±0.00	35.85±0.92	27.60±1.46	40.10±1.76	24.00±6.00
Deutonymph	53.44±0.93	54.00±3.46	43.50±0.82	42.00±3.46	52.28±1.87	39.60±3.05	40.26±0.98	36.00±3.46
Quiescent III	66.55±2.07	38.00±4.00	29.55±0.81	24.00±0.00	34.42±1.19	36.00±3.79	31.73±0.87	20.00±2.00
Total (hours)	640.74±2.05	614.00±2.00	366.30±1.23	338.00±8.71	359.28±1.99	318.80±4.80	284.10±1.83	226.00±3.46
Total (days)	26.69±0.85	25.58±0.08	15.26±0.51	14.08±0.36	14.97±0.83	13.28±0.20	11.83±0.76	9.41±0.14
F test (p<0.05)	NS		NS		NS		**	

Table 5 : Developmental biology of *Tetranychus puschelii* at four constant temperature and relative humidity on papaya

Developmental stages	Mean duration of development on cucumber (h)							
	20±1ºC & 75-80%		24±1ºC & 70-75%		28±1ºC & 65-70%		32±1ºC & 60-65%	
	Female (n=43)	Male (n=4)	Female (n=41)	Male (n=4)	Female (n=41)	Male (n=6)	Female (n=59)	Male (n=4)
Egg	264.00±0.00	264.00±0.00	96.00±0.00	96.00±0.00	68.00±0.00	68.00±0.00	52.00±0.00	52.00±0.00
Egg	230.00±0.00	230.00±0.00	72.00±0.00	72.00±0.00	72.00±0.00	72.00±0.00	54.00±0.00	54.00±0.00
Larva	64.32±1.26	72.00±0.00	63.21±1.11	60.00±2.44	52.24±1.99	43.00±4.49	29.53±1.40	24.00±2.44
Quiescent I	31.39±1.29	34.50±1.50	35.85±0.71	37.50±1.50	49.46±1.35	37.00±3.92	41.53±1.50	39.00±1.73
Protonymph	129.06±1.88	117.00±3.87	62.04±1.03	54.00±2.44	63.36±2.36	49.00±3.60	36.00±1.12	31.50±4.50
Quiescent II	34.04±0.81	33.00±3.87	43.75±0.94	37.50±1.50	48.29±1.04	47.00±3.25	43.84±1.57	31.50±2.87
Deutonymph	50.93±0.75	51.00±3.87	38.19±0.71	36.00±2.44	50.92±1.49	47.00±3.60	35.84±0.89	43.50±2.87
Quiescent III	57.48±2.21	27.00±3.87	34.82±1.11	22.50±1.50	50.34±0.83	49.00±2.40	30.92±0.94	19.50±1.50
Total (hours)	597.25±2.14	564.50±2.87	349.90±1.17	319.50±2.87	386.63±1.61	344.00±2.96	271.69±1.26	243.00±3.87
Total (days)	24.88±0.89	23.52±0.11	14.57±0.48	13.31±0.11	16.10±0.67	14.33±0.12	11.32±0.05	10.12±0.16
F test (p<0.05)	NS		NS		**		NS	

of different hosts and different species of *Tetranychus*. Further, the data of developmental duration for *T. puschelii* on different temperatures in the current study is also comparable with the reports of Ullah et al. (2011) which showed that development of *T. kanzawai* on bean leaf was 24.4, 21.07, 15.6, 12.1, 9.8, 8.2, 6.3, 5.6 and 5.3 days at 15º, 17.5º, 20º, 22.5º 25º, 27.5º, 30º, 32.5º, 35ºC, respectively. Here, the results clearly show the decrease in duration with the increase in temperature. Jamour & Shishehbor (2012) found that *T. turkestani* took 50.11, 16.14, 10.27 and 7.73 days at the temperatures of 15º, 20º, 25º and 30ºC, respectively on cucumber leaves. Pooja (2019) reported that the results of the life history of *T. udaipurensis* between the temperature range of 22ºC and 34ºC ranged from 16.99 to 7.42 days on another cucurbitaceous crop, ridge gourd, which shows the significant difference between the developmental duration of females and males even among all the life stages (incubation period, larval stage, protonymph and deutonymph stages) at different temperatures and also males completed the development comparatively faster than females, which is similar to the results of the present study on *T. puschelii.*

The developmental duration of mites also varies with different hosts and characteristics of the host plant such as the age of the plant, quality, size, shape and structure of the leaf, also the presence of secondary

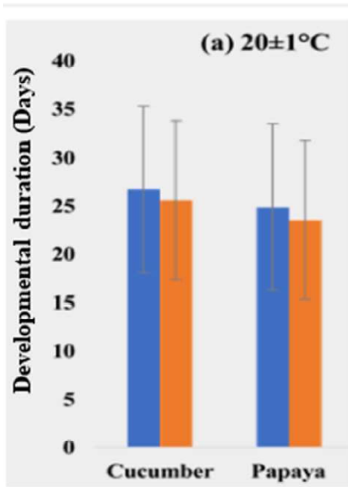

Plate 1. 20±1ºC

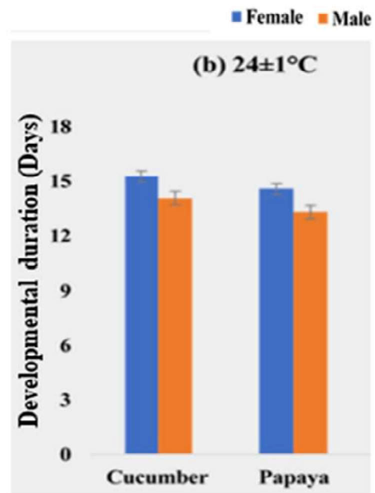

Plate 2. 24±1ºC

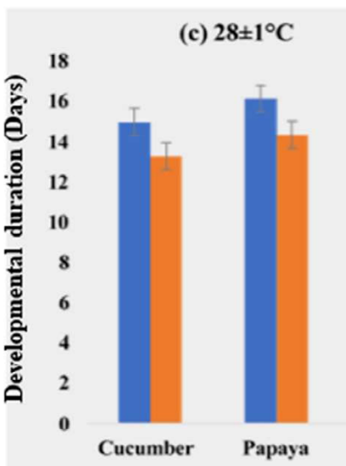

Plate 3. 28±1ºC

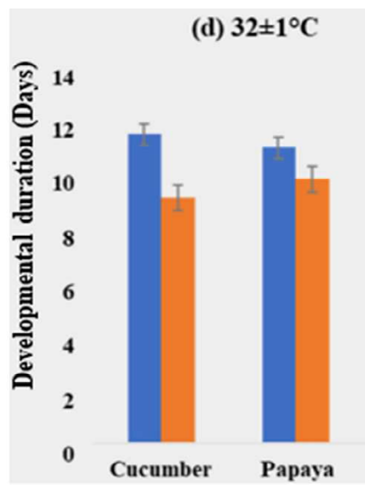

Plate 4. 32±1ºC

Fig. 2 : Developmental duration of *Tetranychus puschelii* on different hosts at different temperatures in the laboratory

Fig. 3 : Shrinked and unhatched eggs of *Tetranychus puschelii* on cucumber at 36±1ºC

metabolites in the plant and plant odour also matters for the survival and development of the mite (Van et al., 2003).

CONCLUSION

For laboratory rearing of *T. puschelii*, cucumber and papaya leaves are the best host plants, temperature of 28ºC and relative humidity of 65 to 70% are the optimum temperature for laboratory rearing and extremely higher (36ºC) and lower (16ºC) temperature are not suitable for *T. puschelii.*

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