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Authored by:

K. P. BETTY AND SANGEETHA G. KAIMAL

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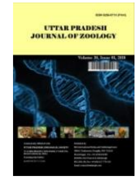

LIFE-TABLE PARAMETERS OF SPIDER MITE *Tetranychus ludeni* Zacher (ACARI: TETRANYCHIDAE) ON *Amaranthus tricolor* L.

K. P. BETTY[1] AND SANGEETHA G. KAIMAL[2*]
[1]Department of Botany, Sacred Heart College, Chalakudy, Kerala-680 307, India.
[2]Department of Zoology, Providence Women's College, Calicut, Kerala-673 009, India.

AUTHORS' CONTRIBUTIONS
This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Studies on the life table parameters of the spider mite, *Tetranychus ludeni* Zacher infesting *Amaranthus tricolor* was initiated in the laboratory following detached leaf culture method at 30 ± 5°C and 70 ± 2% RH. The respective durations recorded for pre-oviposition period, oviposition period and post-oviposition period were 0.75 ± 2, 10.5 ± 0.8 and 0.75 ± 2 days respectively. The total number of eggs laid by an adult female averaged 91.65 ± 3.9 eggs. Life span was recorded to be 11.75 ± 0.7 days. Durations of both sexual and parthenogenetic reproduction were 10.04 ± 0.28 days and 9.65 ± 0.20 days respectively. Shorter duration of development was observed for parthenogenetic development in comparison to that of sexual reproduction. Male:female sex ratio was recorded to be 1-2: 10. A cognitive aspect that reflected was the addition of a new host plant to the so far enlisted hosts for the mite, *T. ludeni*.

Keywords: *Amaranthus tricolor*; spider mite; *T. ludeni*; moulting; longevity and reproduction.

1. INTRODUCTION

The tetranychid mite (spider mite) *Tetranychus ludeni* is a dreadful pest owing to their ubiquitous presence and destructive potentials to a wide range of economically important plants [1-4]. As invasive species, they inflict deleterious effects on host tissues because of their microscopic size, cryptic behaviour, high fecundity, extremely short lifecycle, polyphagous nature and pesticide resistance crops [5,6,1,3,7,8]. This astounding ability of *T. ludeni* to colonize host plants to replenish all the available

**Corresponding author: Email: drsangeethakaimal@gmail.com, sangeethakaimal@gmail.com;*

nutrients, inflict internal injury, stippling, bronzing and chlorosis, cause photosynthetic decline, languish stomatal conductance and reduce transpiration rates has led to considerable loss to agriculturists. Apart from direct damages, *T. ludeni* is known to act as vectors of plant viral diseases *viz.,* (DEMV) [9].

The current host plant of *T. ludeni, Amaranthus tricolor* L. (Amaranthus, collectively known as amaranth), is a cosmopolitan genus of rapidly-growing annual herbs noted for its brilliantly coloured foliage, variegated in shades of red, green, or yellow. Although several species are often considered as weeds, amaranths are valued world-wide as leafy vegetables and ornamentals. The red spinach, *A. tricolor* belonging to family Amaranthaceae is an annual, broadleaved, erect herb, growing up to 1.25m high and is cultivated in Asia for its edible leaves and seed. The simple (often purplish) leaves of spinach are used either raw or in its steamed form in the preparation of salads, soups and stews. The leaves are rich in proteins (3.5%), carbohydrates (6.6%), minerals (calcium, iron, magnesium, phosphorus, potassium, zinc, copper and manganese) and vitamins. The leaves owing to their medicinal value are also used against external inflammation, diuretics (treatment for bladder distress) and to control haemorrhage following abortion. The whole plant is known for its astringent property and a decoction of old plants when taken internally improves vision and strengthens the liver. Leaves of *A. tricolor* showed signs of heavy infestation of the spider mite, *T. ludeni* and therefore the plant was duly considered for regular collection for biological studies.

The current paper focuses therefore on the developmental aspects of *T. ludeni* on *A. tricolor* as a preliminary step to plan intervention tools for IPM for *T. ludeni* control. Selection of *A. tricolor* as the host plant was done owing to the heavy intensity colonization and high degree of damage induced by *T. ludeni* as well as the uniform presence of the plant throughout the study area coupled with their supreme economic status to mankind. The meticulous planning of a proper IPM strategy demands a thorough knowledge of the biology, ecology and behavior of the mite under consideration.

2. MATERIALS AND METHODS

Studies were initiated during the months of September - May in the Acarology division, University of Calicut, Kerala. Rearing of the spider mite, *T. ludeni* was done following detached leaf culture method [10]. Expanded leaves at 2 months of age excised from *A. tricolor* grown in green houses were placed with their adaxial surface facing upwards on moist cotton bed kept in petridishes. When the leaves showed signs of loss of vitality, they were replaced with fresh ones usually after 2 to 3 days interval. Adult *T. ludeni* females (approx. 25) were transferred to the petridishes containing fresh host leaves immediately after collection from the field. The colonies were maintained in the laboratory under standard conditions in an environmental growth chamber set at 30 $\pm$ 5^{o}C and 70 $\pm$ 2% RH. Studies on sexual development were done by introducing few males in each of the culture set along with females. Observations on the different aspects *viz.,* oviposition, incubation, hatching, duration of developmental stages, quiscence and moulting was done using Magnus stereozoom trinocular research microscope at 6hr time intervals. The results were statistically analysed, tabulated and presented as mean $\pm$ SEM. Identification of the species was done by running appropriate taxonomic keys and confirmation of species was done based on the morphological structure of the male aedeagus, which is the diagnostic feature for species level identification [11,5].

3. RESULTS

3.1 Oviposition

T. ludeni females showed preference to the adaxial leaf surface. No site-specific selection was noticed in the case of oviposition. Prior to egg deposition, adult females constructed webbing from silk threads released from a pair of glands near their mouth. Egg deposition followed a random pattern and were often seen glued over the surface of the webbing. Freshly laid eggs were spherical, transparent and colouless. They turned pale yellow the following day and later to orange on the final day of oviposition. The larval gnathosoma, eye spots and legs could be easily perceived through the egg case few minutes prior to the intitiation of the hatching process. The durations of pre-oviposition, oviposition and post-oviposition periods of *T. ludeni* were recorded to be 0.75 $\pm$ 2 days, 10.5 $\pm$ 0.8 days and 0.75 $\pm$ 2 days respectively on *A. tricolor* (Table 1).

Table 1. Duration (in days) of pre-oviposition, oviposition and post-oviposition periods of *T. ludeni* on *A. tricolor*

Pre-oviposition	Oviposition	Post-oviposition
0.75 $\pm$ 2	10.5 $\pm$ 0.8	0.75 $\pm$ 2

n = 35

3.2 Fecundity and Longevity

The total number of eggs laid by adult *T. ludeni* during its reproductive phase was noted minimum on the firat and second days of oviposition. However, fecundity attained peak on the sixth day following which a slow but steady decline was obseerved from the seventh day to the least on the last day of oviposition. The peak daily egg production on the sixth day was 20.9 $\pm$ 0.32 eggs and the least number was 23.2 $\pm$ 0.17 eggs on the final ovipositing day. Fecundity per female of *T. ludeni* on *A. tricolor* averaged 91.65 $\pm$ 3.9 eggs. Further, it was also observed that the mated females exceeded in their fecundity levels in comparison to the fecundity rate as shown by the virgin females (Table 2). The duration of life span of *T. ludeni* averaged 11.75 $\pm$ 0.7 days on *A. tricolor*. The longevity of mated recorded less than virgin females *viz.,* 11.2 $\pm$ 0.01 days and 12.75 $\pm$ 0.2 days respectively (Table 3).

3.3 Hatching

Hatching process was initiated by the appearance of a slit near the apical margin of the egg along with an increase in the size at the equatorial region. The slit further deepened as the furrow laterally moved to meet mid ventrally. The wriggling movements of the emerging larva further aided the process and the egg cases after hatching was found to separate as two distinct halves. The entire sequence of events culminated in 10 - 12 minutes duration. Range of hatchability of eggs was 92%.

3.4 Duration of Developmental Stages (Table 3)

3.4.1 Incubation period

The period between egg laying and hatching of *T. ludeni* was observed to be 3.4 $\pm$ 0.02 days on *A. tricolor*. During this period significant changes were noticed in the shape and colour of the eggs ranging from transparent nature to orangish tinge.

3.4.2 Larval period

Larval period extended from the emergence of larva from the egg to the transformation of inactive quiescent stage. The larva is the smallest life stage, creamy white coloured, with red prominent eye spots and 3 pairs of legs. The larva soon after emergence remained motionless for around 10 minutes before it initiated feeding. The larva with its piercing mouth parts sucked the leaf sap and the feeding process was evident from the rotational movement of the leaf sap in the abdomen of the larva. A change to greenish yellow colour was also observed by the end of the active larval life. The duration recorded was 1.0 $\pm$ 0.03 day. Soon after the active life of larva ceased, it stopped feeding and entered into an inactive stage or the first quiescence. This followed moulting and emergence of the first nymphal stage called protonymph.

3.4.3 Protonymphal period

The first stage nymph called protonymph showed increased size than the larval stage and had 4 pairs of legs. Soon after emergence, the body was pale yellow with green dots on its dorsolateral region. After a few minutes of inactivity, the protonymph initiated feeding, the pattern of which was similar to that of the larva. The protonymphal active period lasted for 1.1 $\pm$ 0.01 days. This followed the beginning of the second quiescent phase and the subsequent moulting into the deutonymphal stage.

3.4.4 Deutonymphal period

The quiescent protonmphal stage culminated with the emergence of the last instar nymph or the deutonymph. Deutonymphal stage showed great similarity with the adult and hence marked sexual dimorphism could be perceived at this stage. It is larger in size than the protonymph and the feeding activity began 10 minutes after moulting was completed. The deutonymphal period on *A. tricolor* averaged 1.5 $\pm$ 0.02 days. AT the end of deutonymphal active life, third quiescence and moulting process into the adult stage followed.

3.5 Adult Stages

Adults of *T. ludeni* could easily be distinguished owing to marked morphological differences. Males appeared to be lesser in number, pale yellow in colour, small sized and spindle shaped with tapering abdomen. They were found gregariously moving faster than the large sized females who were red coloured and with rounded abdomen. The males emerged earlier than females and were found guarding the female quiescent deutonymph to mate as soon as the deutonymph moults into the adult. The males had no role other than reproduction and hence were found to mate multiple times with different females.

Table 2. Fecundity and rate of daily egg production of *T. ludeni* on *A. tricolor*

Number of eggs laid on different days of oviposition										Total number of eggs laid
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
5.0±0.1	9.2±0.31	11.8±0.2	15.2±0.5	17.6±0.1	20.9±0.3	18.3±0.9	12.2±0.4	8.2±0.5	3.2±0.17	98.2 ± 5.5 Mated female
3.2±0.2	5.1±0.22	8.3±0.42	12.9±0.7	14.2±0.5	17.5±0.3	10.8±0.9	6.6±0.55	2.2±0.4	1.0±0.05	85.1 ± 2.2 Unmated female
Mean ± SEM										91.65 ± 3.9

n = 35

Table 3. Duration (in days) of development and longevity of *T. ludeni* on *A. tricolor*

Egg	Larva	1st Quiescence	Proto-nymph	2nd Quiescence	Deuto-nymph	3rd Quiescence	Total duration	Longevity
3.4±0.02	1±0.03	0.75±0.05	1.1±0.01	1±0	1.5±0.02	1±0	9.75±0.08	11.75 ± 0.7
3.01±0.06	1.08±0.03	0.71±0.04	1.10±0.02	1±0	1.75±0.05	1±0	9.65±0.20 Parthenogenesis	12.75 ± 0.2 Unmated
3.13±0.05	1.12±0.02	0.78±0.05	1.26±0.08	1±0	1.75±0.08	1±0	10.04±0.28 Sexual	11.2 ± 0.01 Mated

n = 35

3.6 Quiescent Periods

Quiescent period is a period of zero activity in the life cycle of *T. ludeni.* The mite showed three stages of quiescence, one at the end of active life of each developing stage. Quiescence is marked by the appearance of a covering over the body surface which appeared opaque in the initial stage and later on turned shiny just few minutes prior to moulting. During this period, *T. ludeni* folded its third pair of legs under the hysterosoma and the first two pairs were projected forwards. A unique feature of the tendency of aggregation was exhibited by *T. ludeni* during all the three quiescent periods. The active stages prior to entering quiescence opted for a secluded safe site preferably near the crevices of the mid rib on the foliage and in the shelter of the webbing. They then moved in close proximity and settled close to each other. As more larval and nymphal quiescent stages joined from different directions the colony of quiescent individuals acquired a circular shape. The durations of the 3 quiescent stages of *T. ludeni* were recorded to be 0.75 $\pm$ 0.05, 1.00 $\pm$ 0 and 1.00 $\pm$ 0 day respectively.

3.7 Moulting

Moulting is the emergence of the subsequent life stage from the preceding life stage with an inactive stage of transition or quiescence in between. Aggregation as observed in *T. ludeni* culminated with moulting. A split that appeared on the mid-dorsal region extended either side to meet mid-ventrally. The active movements of the forelimbs of the emerging stage tampered the posterior half of the mouting skin. The entire process took an average time of 20 minutes for completion. However, the anterior part of the exuviae remained inatact due to the backward movement of the mite during emergence. Scattered white exuviae could be seen on the leaf surface in enormous numbers.

3.8 Mating

Sexual reproduction was done by copulation where the males inserted its aedeagus to the vagina of the female by bending its hysterosoma over that of the female. Mating was completed in 10 minutes and soon after the process the males moved away in search of new adult females.

3.9 Total Duration of Development

Developmental stages followed the same pattern as in other Tetranychid representatives. They showed sexual and parthenogenetic modes of reproduction. The sequence of events in both kinds of reproduction was identical. However, parthenogenesis yielded only males while sexual reproduction resulted in both sexes in the ratio of 1-2 male:10 females. The average durations of development of were 9.75 $\pm$ 0.08 days and that of parthenogenesis versus sexual reproduction were 10.04 $\pm$ 0.28 and 9.65 $\pm$ 0.20 days. Shorter duration of development was observed in parthenogenesis compared to that of sexual reproduction.

4. DISCUSSION

Though the pattern of development and sequence of events matched other Tetranychid mites, *T. ludeni* exhibited a unique behavior of the phenomenon called aggregation. This behavior throws light on the unmatched cohesive nature of the colony unlike other spider mites who prefer to enter quiescence solitarily. [12,3,13,14]. Tetranychid mites show a general preference of depositing eggs close to the midrib or major veins of the host leaves [15,7]. However, the spider mite *T. ludeni* had no such ovipositional site preference [14]. The reason for the ovipositional pattern of laying eggs randomly could be the tough nature of the silken web secreted by *T. ludeni* that provided adequate protection to the delicate eggs and the life stages.

The pre-oviposition and oviposition periods of *T. ludeni* recorded by Puttaswamy and Channa Basavanna [16] on brinjal leaves were 0.98 day and 10.85 days. This is almost in concordance with the present results. On the contrary, the post-oviposition periods reported by the authors were three times greater up to 2.4 days. The same authors [17,18] observed the pre-oviposition, oviposition and post-oviposition periods at 19.3^{o}C - 28.4^{o}C and 53% - 88% RH as 1.54 days, 12.75 days and 3.61 days respectively. In the current study, the rate of oviposition in *T. ludeni* attained the highest record on the 6th day. However, oviposition rate reached peak earlier on the 4th day in *T. evansi* [19], later in the 7th day in *T. urticae* [20] and 9th day in *T. ludeni* [21]. Life span of mated females was found lower than that of unmated females. This highlighted negative implication of copulation on the life span of the mite *T. ludeni*. It was also influenced by the rate of daily fecundity [3,13]. Greater the rate of oviposition, lesser was the longevity of females as recorded in the current investigation.

The process of hatching and the formation of slit closely resembled the pattern in *T. neocaledonicus* [14,7]. Unlike other Tetranychid mites, fluid expulsion from the egg was observed at the time of hatching in *T. ludeni*. Moulting and mating process of *T. ludeni* shared similarities with many other spider mites as reported by several authors [11,1]. *T. ludeni* males showed great preference for unmated females who were more gregarious and were stationed on the foliage for extended periods than the mated females. This enhanced the chances for more copulation opportunities. *T. ludeni* copulated multiple times with mature females unlike many spider mites where single mating was recorded. A radical behaviual change from this normal nature was recorded in *T. ludeni* wherein the same female engaged in multiple mating with different males [21,12,22].

The occurance of arrhenotoky has been observed in several tetranychid mite species [14,7]. Such dual reproductive tendency is a means to increase the male population that is otherwise always less in the field. The sequence of processes however matches in the two kind of mechanisms. All the progeny were found to be males in the case of parthenogenetic development while in the sexual reproduction both males and females were produced with a sex ratio of 2 males:10 females. The total durations of development of *T. ludeni* as recorded by Mallik and ChannaBasavanna, 1983 (22.2 days) seemed contrary while that observed by Singh et al., [23] (10.16 days) seemed to coincide with the present findings of *T. ludeni* on *A. tricolor*.

A significant observation on the unique pattern of aggregation was noted in *T. ludeni*. This throws light on the ontogeny of *T. ludeni* since it was repeatedly observed at the onset of every quiescent period [24,21,14]. In-depth investigation in anticipated for future research on these lines to have a better understanding of their behavioual pattern under the influence of pheromones.

5. CONCLUSION

Biological studies of *T. ludeni* on *A. tricolor* clearly reflects on the potential of the mite to rise to the status of major pest. The spider mite completed on an average 3-4 generations in the laboratory conditions as well as in the field and build their population well above the threshold level in no time. The deleterious damage caused to the plant is visible to naked eye only at a very later stage of infestation, which is yet another reason for the serious economic loss to growers. Hence control of such harmful pests is the need of the hour particularly for a state like Kerala where agriculture is the major source of income for the majority. A cognitive aspect that elucidated from the present study was the occurrence of the mite on a rich leafy vegetable crop *A. tricolor* as a new host record to the existing list of hosts of *T. ludeni*. Further exploration of the possibility of new host arenas should be necessitated so as to protect the agricultural wealth of our state from being exploited by these dreadful pests.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Gupta SK. Injurious and beneficial mites infesting agri-horticultural crops in India and their management. Nature books India, New Delhi. 2012;362.
2. Binisha KV, Haseena B. Mite fauna associated with major vegetable crops of Thrissur district, Kerala. Entomon. 2013;38(1):47–52.
3. Saritha C, Ramani N. Population Density and Distribution Pattern of Mites Infesting The Invasive Plant, *Bidens sulphurea* cav. International Journal of Science and Research. 2013;4(7):556–559.
4. Lekha C, Kinathi S. Phytophagous mites infesting vegetable crops of Kerala, India, Persian J. Acarol. 2019;(8)1:69–72.
5. Jeppson LR, Keifer HH, Baker EW. Mites injurious to economic plants. University of California Press. 1994;614.
6. Zhang ZQ. Mites of greenhouses, identification, biology and control. CABI Publishing, Wallington UK. 2003;244.
7. Sangeetha GK. Breeding biology of the vegetable mite on Moringa oleifera Lam (ISBN: 978-3-659-78830-7). Lap Lambert Academic Publishing, Beau Bassin 71504, Mauritius. 2019;81.
8. Young MR, Proctor HC, Dewaard JR, Hebert PD. DNA barcodes expose unexpected diversity in Canadian mites. Molecular Ecology. 2019;28(24):5347-5359.
9. Rajagopalan K. First record of spider mite *Tetranychus ludeni Zacher transmitting* Dolichos Enation Mosaic Virus (DEMV). Current Science. 1974;43(15):488-489.
10. Sangeetha GK, Ramani N. Biological studies of *Tetranychus neocaledonicus* Andre (Acari: Tetranychidae) infesting *Moringa oleifera* Lam. Bulletin of Pure and Applied Sciences. 2007;26A(2):51-57.

11. Gupta SK. The Handbook on Plant Mites of India. Zoological Survey of India Calcutta. 1985;507.
12. Sangeetha GK, Ramani N. Biology of *Tetranychus ludeni* Zacher (Acari: Tetranychidae) – A pest of velvet bean. Indian Journal of Fundamental and Applied Sciences. 2011;1(3):1-6.
13. Gotoh T, Moriya D, Nachman G. Development and reproduction of five *Tetranychus species* (Acari: Tetranychidae): do they all have the potential to become major pests? Experimental and Applied Acarology. 2015;66:453–479.
14. Ristyadi D, He ZX, Wang Q. Dynamics of life history traits in Tetranychus ludeni Zacher in response to fluctuating temperatures, Systematic and Applied Acarology. 2019; 24(11):2272–2277.
15. Gotoh T, Saito M, Suzuki A, Nachman G. Effect of constant and variable temperatures on development and reproduction of the two spotted spider mite *Tetranychus urticae* (Acari: Tetranychidae). Systematic and Applied Acarology. 2014;64:465–478.
16. Puttaswamy, Channabasavanna GP. Influence of host plants on the development, fecundity and longevity of *Tetranychus ludeni* Zacher (Acari: Tetranychidae). Indian Journal of Acarology. 1981;5:80-84.
17. Puttaswamy, Channabasavanna GP. Effect of temperature and relative humidity on the development and oviposition of *Tetranychus ludeni* (Acari: Tetranychidae). Indian Journal of Acarology. 1980a;4(1):31-40.
18. Puttaswamy, Channabasavanna GP. Life history of T. ludeni (Acari: Tetranychidae) under field condition. Indian Journal of Acarology. 1980b;4(1):41-48.
19. Qureshi AH, Oatman ER, Fleschner CA. Biology of the spider mite, *Tetranychus evansi* Pritchard and Baker. Annual Entomological Society of America. 1969;62(4):898-903.
20. Shih CT, Poe SL, Cromroy HL. Biology, life table and intrinsic rate of increase of *Tetranychus urticae*. Annual Entomological Society of America. 1976;69:362-364.
21. Oku K, Yano S, Osakabe M, Takafuji A. Mating strategies of *Tetranychus kanzawai* (Acari: Tetranychidae) in relation to mating status of females. Annual Entomological Society of America. 2005;98(4):625-628.
22. Prasad S, Raghuraman M, Singh J. Effect of Temperature and Relative Humidity on the development of Red Spider Mite, *Teteranychus ludeni* Zacher at Varanasi. International Journal of Development Research. 2015;5(4):4021-4024.
23. Singh P, Somchoudhury AK, Mukherjee AB. The influence of natural enemy complex on the population of *Aceria litchii* (Acari: Eriophyidae). In: Progress in Acarology. 1989; 2:361-367.
24. Mallik B, Channabasavanna GP. Life history and life tables of *Tetranychus ludeni* and its predator *Amblyseius longispinosus* (Acari: Tetranychidae; Phytoseiidae). Indian Journal of Acarology. 1983;8:1-12.