Indian Journal of Entomology 86(2): 472-477 (2024) DoI. No.: 10.55446/IJE.2023.774

POPULATION DYNAMICS OF EMERGING SPIDER MITE PEST *TETRANYCHUS UDAIPURENSIS* GUPTA & GUPTA

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ABSTRACT

Temperature related development and demography of emerging spider mite pest *Tetranychus udaipurensis* Gupta and Gupta were studied on two vegetable host plants ridge gourd and French bean at four different temperature (22º-34ºC) and humidity conditions (67-80%). Development of *T. udaipurensis* female was faster-7.31 days on French bean and 7.42 days on ridge gourd, respectively at 34ºC. For reproduction (female longevity, fecundity and sex ratio) and demography, the favourable temperature range was 26º-30ºC. Chief demographic parameters viz., mean generation time, doubling time, net reproduction rate and intrinsic rate of natural increase on the preferred host French bean was 16 to 20 and 2.98 to 3.80, 42 to 48 mites and 0.200 to 0.248 female offsprings/ day, respectively. Under the consequence of changing climatic conditions, *T.udaipurensis* might emerge as potential pest of vegetable crops, more particularly of French bean.

Key words: *Tetranychus udaipurensis*, emerging spider mite, developmental biology, demography, French bean, Ridge gourd, temprature, humidity, longevity, fecundity, sex ratio

Members of mite family Tetranychidae, commonly known as spider mites are important pests of agricultural crops, including cereals, pulses, millets, vegetables, plantation crops, ornamental and medicinal plants (Vacante, 2015). They suck the plant sap and weaken the plants, which results in significant loss in the yield of such crops. With the introduction of, newer crop varieties, intensive cultivation practices and expected probable changes in the climatic conditions, mites are being blessed with wider range of host plants. As a result, mites tend to cause potential damage on crops particularly, the vegetable crops. In the recent past, the spider mites are found expanding their geographical distribution and as pests of crops accounting for serious crop damage. *Tetranychus udaipurensis* Gupta and Gupta was first described by Gupta and Gupta on brinjal from Udaipur, Rajasthan. After a time gap of nearly 20 years, Singh (2015) reported *T. udaipurensis* on apple (*Malus domestica*) in Kinnaur (Kalpa). Zeity (2011) reported the mite species on *Asystasia gangetica* (at GKVK campus Bangalore) and malvaceous weed (in Mysore); on *Diplocyclos palmatus* from Hemmige-Maddur. It was also reported on many cultivated crops like *Coccinea,* drumstick and papaya in the Bapatla region of Andhra Pradesh (Srinivasa et al., 2018 a-d). The spider mite species is expanding its geographical distribution by inhabiting agricultural cropped area and getting adapted to newer conditions of the crop plants available therein. Under the changing global pest scenario, there are sporadic occurrences of hitherto lesser known spider mite species, wherever and whenever the climatic conditions were found in their favour i.e., variation in the ambient temperature and host plant qualities. In this context, some of the hitherto unknown spider mite species are in the forefront to cause considerable damage like other conventional tetranychid mite species, like two spotted spider mite *Tetranychus urticae*. *T. udaipurensis* is expanding its host range to vegetables, fruit crops etc., becoming an important emerging pest of the crops.

MATERIALS AND METHODS

Tetranychus udaipurensis (UAS-B:2410) from infested soybean plants in the experimental block of Department of Crop Physiology at GKVK campus, Bangalore were collected and brought to the laboratory in separate polyethylene bags. At least 8 to 10 slide mounts were prepared separately and mainly male aedeagal characters studied using standard taxonomic keys. After species level identification using morphological characters, fifty teliochrysalis females (quiescent deutonymph) along with 1 to 2 attending males were randomly picked from the infested leaf sample and transferred onto separate 2.5 x 2.5 cm mulberry leaf discs placed on wet cotton wad in 6" inches petri plates and allowed for colonization for at least 10-15 days (Excised leaf disc technique). Later, mite colonies from different leaf discs were pooled and used as a purified

nucleus culture of *T. udaipurensis*. The purified culture was further used for molecular characterization and investigations on temperature dependent mite survival, biology and demography on two different vegetable host plants i.e., french bean and ridge gourd.

Life history of *T. udaipurensis* was studied at four constant temperatures and humidity conditions viz., 22± 1ºC, 26± 1ºC, 30±1ºC and 34± 1ºC on excised leaves of French bean & Ridge gourd with 16h: 8h L: D conditions in a BOD incubator. Initially a cohort of 30 eggs laid on 2.5 x 2.5 cm leaf discs were transferred individually using a fine camel hair brush onto 30 separate 1.5 x 1.5 cm fresh leaf discs kept on wet foam placed in 9 " x 6 " polyethylene trays. The data on development of the mite from egg hatching to adult emergence was recorded under a stereo-binocular microscope, every 3 to 6 hours till egg hatching and every 6 hours further, till the adults emerged. Developmental stages were transferred to fresh leaf discs as and when necessary or required. Duration of different developmental stages such as larva, quiescent 1 (larvochrysalis), protonymph, quiescent 2 (nymphochrysalis), deutonymph and quiescent 3 (teliochrysalis) was computed. Other observations of life history study included recording the sex of the emerging adult, longevity etc.

To study reproduction and population parameters, thirty female teliochrysalis stages were selected from the pure nucleus culture maintained in the laboratory on the respective hosts and were individually transferred to fresh 1.5 x 1.5 cm leaf bits of respective host plants, French bean & Ridge gourd. To ensure mating two male adults of the corresponding mite species were released on each of these leaf discs. After the emergence of the female from the teliochrysalis stage, preoviposition period was recorded by observing the leaf discs every 12 hrs. Further, the number of eggs laid was recorded daily. Observations were recorded at 24 hours interval till the females stopped laying eggs and died naturally. Since the life span of male mite was short, as and when they were found dead on the leaf disks, were replaced with the fresh ones. Ovipositing females were carefully transferred onto fresh leaf bits daily and the eggs laid were reared for further development to the emergence of adults and sex ratio of the progeny was also worked out.

Reproduction attributes viz., preoviposition, oviposition, post-oviposition, fecundity and proportion of male and female off-springs (♂: ♀) recorded across four different temperatures and humidity conditions. The data were compared to know the influence of temperature across the host plants. Age specific life table of *T. udaipurensis* on the respective host plants was constructed separately. Demographic characteristics such as, mean generation time (T), net reproduction rate (R_o), gross reproduction rate (GRR), finite rate of increase (λ), intrinsic rate of natural increase (r_m) and doubling time (DT) were calculated following the procedure suggested by Birch (1948) and Atwal and Bains (1974) as follows:

I. Net reproduction rate, R_o (no. of female off-springs/ female/generation) is the average number of new born females produced by a female during its entire life time. It is the sum of the products of lx and mx i.e., $R_o = \Sigma$ lxmx; where,
   lx = proportion of females alive at age interval x; mx=the number of female off-springs produced by the surviving female at the age interval x; lxmx= product of the proportion of females live at age interval x and the number of female off-springs per original female produced at the age interval x.

II. Mean generation time (T) (days) is the average age of parenthood. Accurate calculation of T is made by weighing each age by its total fecundity (lxmx) and dividing it by R_o as, $T = \frac{\sum xlxmx}{Ro}$

III. Finite rate of increase in number (no. of female off-springs/ female/ day) (λ) was calculated using the formula, $\lambda = \text{antiln}\frac{\ln Ro}{T}$ Or $\lambda = e^{rm}$
   where, R_o and T are specifically defined.

IV. Intrinsic rate of natural increase or innate capacity for increase in numbers, r_m (no. of female off-springs/female/day) is the maximal rate of increase by the combination of food, temperature, quality of food, etc. The r_m was computed using the formula, $r_m = \ln(\lambda)$, where, ln = Natural log; λ = Finite Rate of Increase in number

V. Doubling time: The doubling time is the time it takes for a population to double in size, Doubling time: $\frac{\ln 2}{r_m}$ where, ln = Natural log; r_m = Intrinsic rate of natural increase

Duration of different developmental stages and reproduction attributes were expressed as mean± SE, while data of total development (female and male) were analysed following one-way ANOVA. The standard error of different demographic parameters was estimated by bootstrapping technique and for comparison across different rearing temperature conditions, data were analysed using Tukey's HSD test in the statistical software SPSS 23.

RESULTS AND DISCUSSION

Effect of temperature was evident on the survival of *T. udaipurensis* on French bean as well as ridge gourd leaf discs. 22ºC egg hatchability was 95.89% survival of larval stage was 86.67%, of protonymphal was 96.15% and adult emergence was complete i.e., 100% and overall survival was 83.33%. The corresponding survival values for different life stages on ridge gourd were, 87.50, 80, 100, 84.62 and 100%, with the overall survival from egg to adult was 73.33%. Constant temperature of 30ºC affected the survival at the egg and larval stages of *T. udaipurensis* on French bean (94.32 & 83.33%, respectively) and on Ridge gourd (98.04 & 86.67, respectively). As the rearing temperature conditions increased from 22ºC to 26ºC, increase in overall surviving ability (from egg to adult emergence) was evident on French bean (83.33 to 93.33%). But with the increase in rearing temperature to 30ºC and beyond, the mite survival decreased to 70% at 34ºC rearing temperature on ridge gourd (Table 1). Still at 26ºC the overall survival was highest, 93.33% which could be the optimum temperature requirement of *T. udaipurensis* on its preferred host French bean compared to 80-83.33% at other temperatures. Life history data of *T. udaipurensis* generated on French bean and Ridge gourd are presented in Fig. 1. It revealed that the time taken by mite to complete its development from egg to adult across different temperatures was varying with the increase in the temperature i.e., as the temperature increased the developmental time was reduced. The time taken by the mite to complete development from egg to adult for female was 14.64, 9.92, 7.81 and 7.31 days and for male it was 13.76, 9.44, 6.83 and 6.46 days on French bean. Whereas 16.99, 11.04, 8.49 and 7.42 days for female and 16.08, 10.20, 7.10 and 6.52 days for male on Ridge gourd at temperatures 22, 26, 30 and 34ºC, respectively. Both female and male mites developed faster at 34ºC and developed slower at 22ºC on French bean and Ridge gourd, respectively (Fig. 1).

Across host plants, *T. udaipurensis* tends to develop faster (with shorter duration) with the increasing rearing temperature conditions (Fig. 1). Mites preferred French bean plants for development compared to Ridge gourd at all rearing temperatures in the study. No information is available on mite's biological characteristics since the time the mite species was described (Gupta and Gupta, 1994), except just recording of this mite from important vegetable crops like *Coccinea*, drumstick in Andhra Pradesh by Srinivasa et al. (2018 a-d) and cowpea, ash gourd and brinjal in Kerala by Arunima (2017). Reproduction of *T. udaipurensis* on two host plants across four temperatures and humidity conditions are shown in Table 2. The demography representing Mean Generation Time (T), Gross Reproduction Rate (GRR), Net Reproduction Rate (R_o), Doubling Time (DT), Finite Rate of Increase (λ), Intrinsic Rate of Natural Increase (r_m) computed from the age specific life table are presented in Table 3 and depicted in Figs. 2 and 3 (age specific fecundity). Data with regard to survival of the mated females at constant temperatures (22ºC, 26ºC, 30ºC and 34ºC) on French bean and Ridge gourd revealed that the female survived for 21.25, 14.74, 16.75 and 11.50 days on French bean and for 22.10, 14.05, 17.54 and 10.70 days on ridge gourd, respectively. The mated female laid an average of 41.75, 46.42, 64.90 and 38.15 eggs over a period of 17.05, 12.37, 14.05 and 8.15 days on French bean and 40.94, 42, 46.92 and 25.95 eggs over a period of 16.84, 11.47, 14.04 and 8.15 days on Ridge gourd, respectively. The survival of *T. udaipurensis* female on both the host plants was high at 22ºC, while it's fecundity was highest at 30ºC (46.92 and 64.90 eggs, respectively).

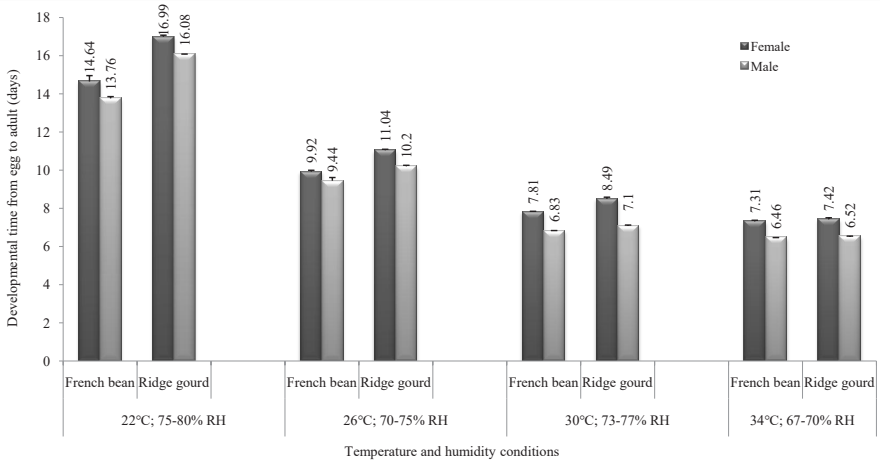

Fig. 1. Development of *T. udaipurensis* on French bean and ridge gourd

Table 1. Effect of temperature on survival of *T. udaipurensis* on two host plants

Temperature (ºC)	Egg hatchability (%)		Larva (%)		Protonymph (%)		Deutonymph (%)		Adult emergence (%)		Overall development (%)	
	French bean	Ridge gourd	French bean	Ridge gourd	French bean	Ridge gourd	French bean	Ridge gourd	French bean	Ridge gourd	French bean	Ridge gourd
22	95.89	87.50	86.67	80	96.15	100	100	84.62	100	100	83.33	73.33
26	100	86.67	93.33	96.67	100	100	100	86.21	100	100	93.33	83.33
30	94.32	98.04	83.33	86.67	100	100	96	100	100	100	80	86.67
34	100	96.67	90	76.67	83.33	100	80	91.30	100	100	80	70

Table 2. Reproduction of *T. udaipurensis* at different temperature and relative humidity conditions

Reproduction parameters	22±1ºC; 75-80% RH		26±1ºC; 70-75% RH		30±1ºC; 73-77% RH		34±1ºC; 67-70% RH	
	French bean	Ridge gourd	French bean	Ridge gourd	French bean	Ridge gourd	French bean	Ridge gourd
Pre-oviposition period (days)	2.60±0.18 [a]	3.26±0.36 [a]	1.16±0.37 [a]	1.42±0.51 [a]	1.50±0.15 [a]	2.25±0.12 [b]	1.70±0.10 [a]	1.45±0.11 [a]
Oviposition period (days)	17.05±1.09 [a]	16.84±1.28 [a]	12.37±2.95 [a]	11.47±1.37 [a]	14.05±0.85 [a]	14.04±0.44 [a]	8.15±0.30 [a]	8.15±0.42 [a]
Post-oviposition period (days)	1.60±0.11 [a]	2.00±0.17 [a]	1.21±0.21 [a]	1.58±0.32 [a]	1.20±0.17 [a]	1.25±0.18 [a]	1.65±0.16 [a]	1.10±0.42 [a]
Female longevity(days)	21.25±1.09 [a]	22.10±1.11 [a]	14.74±2.92 [a]	14.05±1.23 [a]	16.75±0.83 [a]	17.54±0.36 [a]	11.50±0.21 [a]	10.70±0.36 [a]
Total number ofeggs/female	41.75±4.11 [a]	40.94±5.02 [a]	46.42±9.62 [a]	42.00±4.92 [a]	64.90±5.96 [a]	46.92±2.98 [a]	38.15±2.77 [a]	25.95±0.94 [a]
Sex ratio (female: male)	2.29:1 [a]	2.02:1 [a]	4.52:1 [a]	4.55:1 [a]	3.06:1 [a]	2.16:1 [b]	2.68:1 [a]	3.30:1 [b]

Values with same alphabetical superscript across columns in each temperature-humidity regime not significant as per Tukey's HSD test ($p< 0.05$)

Table 3. Demography of *T. udaipurensis* at different temperature and relative humidity conditions

Demographic parameters	22±1ºC; 75-80% RH		26±1ºC; 70-75% RH		30±1ºC; 73-77% RH		34±1ºC; 67-70% RH	
	French bean	Ridge gourd	French bean	Ridge gourd	French bean	Ridge gourd	French bean	Ridge gourd
Mean generation time (T)	27.86±0.18[a]	29.67±0.17 [b]	20.12±0.17 [a]	20.89±0.24 [a]	16.42±0.12 [a]	18.10±0.17 [b]	12.93±0.20 [a]	13.14±0.19 [b]
Doubling Time (DT)	5.98±0.05 [a]	6.50±0.05 [b]	3.80±0.04 [a]	4.32±0.06 [b]	2.98±0.02 [a]	3.71±0.04 [b]	2.97±0.07 [a]	3.15±0.07 [b]
Gross reproductiverate (GRR)	30.88±0.10 [a]	29.16±0.12 [a]	79.00±0.34 [a]	41.88±0.27 [b]	54.59±0.21 [a]	33.39±0.18 [b]	26.94±0.20 [a]	22.28±0.19 [b]
Net reproductiverate (R)	26.30±0.11 [a]	24.44±0.10 [a]	42.26±0.26 [a]	32.70±0.236 [b]	47.73±0.23 [a]	31.70±0.19 [b]	25.18±0.21 [a]	22.14±0.19 [b]
Finite rate of increase (λ)	1.130±0.001 [a]	1.118±0.001 [a]	1.224±0.002 [a]	1.212±0.003 [a]	1.284±0.002 [a]	1.235±0.003 [b]	1.373±0.01 [a]	1.35±0.01 [b]
Intrinsic rate of natural increase (r_m)	0.122±0.001 [a]	0.111±0.001 [b]	0.20±0.001 [a]	0.19±0.002 [a]	0.248±0.002 [a]	0.209±0.002 [b]	0.30±0.00 [a]	0.28±0.00 [b]

Values with same alphabetical superscript across columns in each temperature-humidity regime not significant as per bootstrapping followed by Tukey's HSD test ($p< 0.05$)

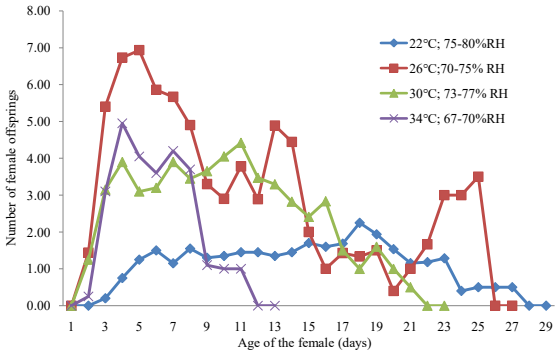

Fig. 2. Age specific fecundity of *T. udaipurensis* on French bean

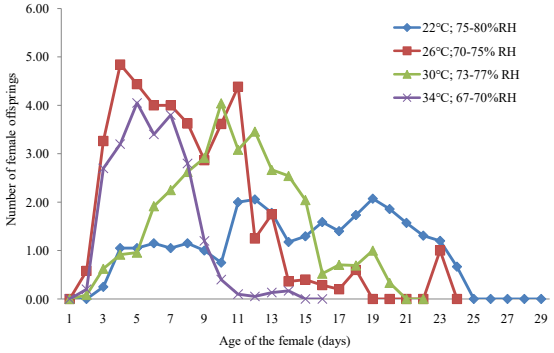

Fig. 3. Age specific fecundity of *T. udaipurensis* on ridge gourd

On French bean at four different temperatures the important demographic parameter, r_m (number of female offsprings/female/day) was 0.122, 0.20, 0.248 and 0.30; R_o (number of female offsprings/ female/ generation) was 26.30, 42.26, 47.73 and 25.18; T (Mean Generation Time) was 27.86, 20.12, 16.42 and 12.93 (Table 3). On ridge gourd the r_m value was 0.111, 0.190, 0.209 and 0.28 and Net Reproduction Rate was 24.44, 32.70, 31.70 and 22.14; Mean Generation Time of 29.67, 20.89, 18.10 and 13.14 days, respectively. There was much difference in r_m values at four temperature conditions; was highest at 34ºC i.e., 0.30 on French bean and 0.28 on Ridge gourd (Table 3). At 26ºC the mated female started laying more number of eggs from 3rd day of its emergence, successive peaks on 6th, 13th and 25th day after emergence on French bean and laid a maximum of 7 eggs/day. On ridge gourd also the female started laying eggs from third day of its emergence which reached peak on 4th and 11th day to lay maximum of 5 eggs/day (Figs. 2 and 3).

As there is no relevant data available on either life history or reproductive capabilities of *T. udaipurensis*, has been compared with the other tetranychid mite pest of vegetable crops. When our data was compared with the biology of *T. neocaledonicus* on lima bean (*Phaseolus lunatus*) under a controlled environment of 25± 1°C and 75± 10% relative humidity (RH), with 12-h photoperiod, mite's average life cycle of female and male was 11.94 and 11.48 days, respectively (Gomes Neto et al., 2017), while *T. udaipurensis* in our study completed life cycle in 9.92 days for female and 9.44 days for male on French bean at 26°C. For reproduction attributes of the mite, favourable rearing temperature ranged from 26º-30ºC on both host French bean and Ridge gourd. Longevity of mated female, oviposition period and life time fecundity of *T. udaipurensis* on French bean and Ridge gourd leaf discs were 15-18 days; 11-14 days; 46-65 eggs and 14 to 18 days; 11-14; 42-47 eggs, respectively. French bean supported the population performance of *T. udaipurensis*, particularly at the temperature range of 26º - 30 ºC and is compared with that of strawberry mite *T. turkestani* studied by Karami and Shishehbor (2012) at four constant temperatures of 15°, 20°, 25° and 30°C, when the mean female longevity ranged from 30.22 ± 2.88 days at 15°C to 5.78± 0.10 days at 30°C and mites fecundity ranged from 23.11 to 49.95 eggs/female. Riahi et al. (2013) studied reproduction and population characteristics of *T. urticae* on peach leaves at 13-33ºC in the laboratory at 25º, 27º, 30º and 33°C, mean egg production range/ female was 40.09 to 21.33. The mean female longevity ranged from 12.91 to 6.53 days.

The intrinsic rate of natural increase (r_m) value has been a key demographic parameter for predicting the population growth of an animal under a given set of environmental conditions (Ricklefs and Miller, 2000). Sabelis (1985 and 1991) and Gotoh and Gomi (2003) providing an extensive review of life history parameters of tetranychid mites showed that r_m values ranged from 0.160-0.293/ day at 25ºC, the similar r_m values were obtained for *T. urticae* in the present study when r_m values ranged from 0.19 -0.20/day on Ridge gourd and French bean at 26 ºC. Critical perusal of biological data of *T. udaipurensis* generated across four constant rearing temperature and humidity conditions in our study indicated more supportive survival, development, reproduction and demography of *T. udaipurensis* on French bean and hence French bean could be a more preferred host of mite species. Thus it may be inferred that *T. udaipurensis* might probably emerge as economically important pest of French bean when the prevailing ambient temperature conditions range from 26º to 30ºC. The data generated from our study helps to visualize the similar occurrence for their emerging spider mite species as pests on important vegetable crops and prepare a contingent plan of timely control or management.

ACKNOWLEDGEMENTS

The authors thank the ICAR Project on Agricultural Acarology for the laboratory facilities.

FINANCIAL SUPPORT

The authors have no relevant financial support to disclose.

AUTHOR CONTRIBUTION STATEMENT

Contributed in the laboratory observations on biology and demography (Pooja); Research proposal framework and draft corrections (NS).

CONFLICT OF INTEREST

No conflict of interest.

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(Manuscript Received: September, 2022; Revised: May, 2023;
Accepted: May, 2023; Online Published: June, 2023)
Online First in www.entosocindia.org and indianentomology.org Ref. No. e23774