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Archana N Borkar
Post Graduate Institute, Department of Entomology, Dr. Panjabrao Deshmukh Krushi Vidyapeeth, Akola, Maharashtra, India

AV Kolhe
Post Graduate Institute, Department of Entomology, Dr. Panjabrao Deshmukh Krushi Vidyapeeth, Akola, Maharashtra, India

DB Undirwade
Post Graduate Institute, Department of Entomology, Dr. Panjabrao Deshmukh Krushi Vidyapeeth, Akola, Maharashtra, India

Corresponding Author:
Archana N Borkar
Post Graduate Institute, Department of Entomology, Dr. Panjabrao Deshmukh Krushi Vidyapeeth, Akola, Maharashtra, India

Biology and life studies of *Tetranychus macfarlanei* on okra

Archana N Borkar, AV Kolhe and DB Undirwade

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Abstract
Present experiment was carried out on biology and life studies of red spider mite, *Tetranychus macfarlanei* on okra under laboratory conditions at 30.8-35.1^{0}C temperature and 64.5-74% relative humidity at Dr. P. D. K. V., Akola. The total developmental period of *T. macfarlanei* from egg to adult emergence is recorded less in male (9.0 ± 0.17 days) than female (10.32 ± 0.19 days). *T. macfarlanei* showed a sexual and arrhenotokous parthenogenesis. Mated female produced a progeny in the ratio 1 male: 4.14 females; whereas, unmated female produced only males. Egg viability was recorded as 93.2 ± 1.17 percent. Adult longevity for male, mated female and unmated female was 11.05 ± 0.99 days, 11.68 ± 1.68 days and 12.45 ± 1.48 days respectively.

Keywords: Biology, *Tetranychus macfarlanei*, okra, egg viability, adult longevity

Introduction
Tetranychus mites have been reported to cause a loss of 7 to 48% in okra fruit yield [1]. Sucking of both nymph and adult of spider mite on the leaf cell sap resulted in characteristic of speckled, stippling appearance of leaves. Large colonies of spider mite produce very fine webbing around the leaves and flowers in which they feed and go toward the top of plants where they tend to congregate. They typically colonize the undersurface of leaves. Pestiferous spider mite biology is characterized by arrhenotokous reproduction, a short generation time, high fecundity, rapid dispersal, effective exploitation of new feeding sites and rapid development of resistance to acaricides [2]. The spider mite has five life stages i.e. egg, larva, protonymph, deutonymph and adult. At the end of each active larval and nymphal stage, there are quiescent phases called nymphochrysalis, deutochrysalis and teliochrysalis [3]. Since the biological development and intensity of infestation of red spider mite, changes with locality, host plant and available temperature and relative humidity in that locality, it is desirable to have a thorough understanding of the biological development of the spider mite in particular locality with prevailed temperature and relative humidity, which will lead to the development of suitable management program in that particular locality. Hence, a research was done on biology and life studies of *T. macfarlanei* which was recorded as the predominant species on okra at Vidarbha region.

Materials and Methods
The biological development and life history traits of red spider mite were studied on okra (variety: *Arka Anamika*) following the leaf disc method [4] at Department of Entomology, Dr. P. D. K. V., Akola, in 2018 under laboratory conditions at 30.8-35.1^{0}C temperature and 64.5-74% relative humidity. The developmental period and morphology of mite was observed and recorded on freshly laid fifty eggs with the help of a stereo binocular microscope at 4 hours interval until their maturity. On emergence, the adult mites were sexed out to work out the developmental duration of different life stages separately for males and females. Morphometric parameters also recorded with the help of micrometers (µm) using phase contrast microscope and ocular micrometers. Observations on mating behaviour, pre-oviposition, oviposition and post-oviposition periods were recorded to study the sexual development of mated and unmated female. The number of eggs laid by the mated as well as unmated females was recorded on daily basis till the death of the female. The eggs laid by each mated as well as unmated female for the first five days were reared and the percent egg viability was worked out. The emerging mites were sexed out after reaching adulthood to determine the sex ratio [5].

Longevity of newly emerged male, unmated and mated female was determined.

Results and Discussion

The life cycle of *T. macfarlanei* consisted of egg, larva, protonymph, deutonymph and adult and a short quiescent stages *viz*., nymphochrysalis, deutochrysalis and teleiochrysalis after each mobile, immature stage.

Morphology, morphometric parameters and developmental duration

Egg: Females laid spherical eggs either singly or in group on the webbing, leaves, often near the veins and midrib of the leaves of okra. Freshly laid eggs resembled water droplet which turned blackish, brownish or yellowish prior to hatching. Two red coloured dots represent to the simple eyes and were clearly visible on eggs prior to hatching. Similar observations were reported earlier by many scientists [6, 7, 8]. The incubation period was 3.55 ± 0.15 and 3.87 ± 0.07 days for male and female respectively (Table 1). The diameter of egg was measured as 147.69 ± 15.73 µm (Table 2). The eggs diameter was reported 0.13 ± 0.01 mm with incubation period of 3.57 ± 0.38 and 3.88 ± 0.33 days for male and female respectively in *T. macfarlanei* on soybean [8].

Larva: Newly emerged larva was light yellowish, tiny, almost spherical. Near the end of larval period two dark specks were observed dorso-laterally. Two pair of red coloured simple eyes was clearly distinguishable on the dorsal pro-podosoma at this stage. Larval period for male and female was recorded as 1.52 ± 0.21 and 1.92 ± 0.07 days respectively (Table 1). The larva measured 182.33 ± 25.94 µm in length and 130.22 ± 14.55 µm in breath (Table 2). The larval body was measured about 190.0 ± 0.02 µm in length and 140.0 ± 0.01 µm in breadth with larval period of 2.18 ± 0.17 and 2.36 ± 0.19 days for male and female respectively [8].

Table 1: Developmental period of different life stages of *T. macfarlanei*

Stage	Developmental period (Days)			
	Male		Female	
	Mean ± S.D. *	Range	Mean ± S.D.*	Range
Incubation (Egg)	3.55 ± 0.15	3.38- 3.92	3.87 ± 0.07	3.74-3.96
Larva	1.52 ± 0.21	1.08-1.83	1.92 ± 0.07	1.75-2.02
Nymphochrysalis	0.61 ± 0.06	0.48-0.69	0.78 ± 0.04	0.71-0.85
Protonymph	1.04 ± 0.04	1.00-1.17	1.35 ± 0.09	1.01-1.58
Deutochrysalis	0.63 ± 0.04	0.54-0.69	0.56 ± 0.03	0.50-0.65
Deutonymph	1.02 ± 0.02	1.00-1.06	1.06 ± 0.04	1.01-1.17
Teleiochrysalis	0.62 ± 0.05	0.53-0.73	0.77 ± 0.03	0.71-0.85
Total development period	9.0 ± 0.17	8.62-9.26	10.32 ± 0.19	9.87-10.72

(*Mean value of fifty observations)

Nymph chrysalis: Nymphochrysalis is the first quiescent stage, which was characterized by the extension of the anterior two pairs of legs straight forward with first pair of tibia bend underneath the legs and kept close to each other. The posterior pair of legs were extended backwards and held close to the side of opisthosoma. This stage ends with the first moulting. In compare to larval stage nymphochrysalis was shinier, bigger, oval shaped and dark green in colour. This stage ends in 0.61 ± 0.06 days in male while, in female the period was 0.78 ± 0.04 days (Table 1). This stage measured 251.04 ± 16.65 µm in length and 148.81 ± 3.77 µm in width (Table 2). Earlier nymphochrysalis period was reported as 0.62 ± 0.05 and 0.77 ± 0.06 days for male and female respectively with body length measured as 230 ± 0.01 µm and breadth measured 140 ± 0.02 µm [8].

Table 2: Morphometrical observations of different developmental stages of *T. macfarlanei*

Stage		Length (µm) ± S.D.*	Width (µm) ± S.D.*
Egg (Diameter)		147.69 ± 15.73	------
Larva		182.33 ± 25.94	130.22 ± 14.55
Nymphochrysalis		251.04 ±16.65	148.81 ± 3.77
Protonymph		290.78 ±12.93	148.54 ± 4.00
Deutochrysalis		338.22 ± 23.03	187.68 ± 8.16
Deutonymph	Female	442.19 ± 27.76	225.45 ± 8.31
	Male	322.10 ± 17.35	174.49 ± 8.01
Teleiochrysalis	Female	472.10 ± 20.47	243.67 ± 12.00
	Male	347.59 ± 15.73	181.09 ± 9.45
Adult	Female	499.12 ± 35.51	252.98 ± 8.74
	Male	370.55 ± 16.28	165.49 ± 5.48

(*Mean value of ten observations)

Protonymph: Protonymph is a first nymphal stage which possesses four pairs of legs. Protonymph was larger in size and darker in colour than larva and was with bigger dark specks on dorsal part of idiosoma. The protonymphal period for male was 1.04 ± 0.04 and 1.35 ± 0.09 days for female (Table 1). This stage measured to 290.78 ± 12.93 µm in length and 148.54 ± 4 µm in breath (Table 2). Previously the protonymphal period of male was reported 1.59 ± 0.32 days and that of female 1.79 ± 0.42 days respectively. The length and breadth of protonymph was measured as 0.35 ± 0.03 and 0.20 ± 0.03 mm for female and male [6, 8].

Deutochrysalis: Deutochrysalis is the second quiescent stage, lasted for 0.63 ± 0.04 days for male and 0.56 ± 0.03 days for female (Table 1). Deutochrysalis measured 338.22 ± 23.03 µm in length and 187. 68 ± 8.16 µm in breath (Table 2).

Deutochrysalis period was reported as 0.57 ± 0.06 and 0.77 ± 0.10 days for male and female respectively with the length and breadth of deutochrysalis measured as 0.32 ± 0.05 and 0.16 ± 0.04 mm for female and male [8].

Deutonymph: Deutonymph is the second nymphal stage, it was carmine in colour. Sexual dimorphism was visible at this stage and onward with the larger and broader female; male is smaller than female and with elongated abdomen. The deutonymph period was 1.02 ± 0.02 days and 1.06 ± 0.04 days for male and female respectively (Table 1). Deutonymph in male is measured to 322.10 ± 17.35 µm in length and 174.49 ± 8.01 µm in width while in female it is measured as the 442. 19 µm in length and 225.45 ± 8.31 µm in width (Table 2). Earlier researchers reported deutonymphal period as 1.16 ± 0.07 and 1.27 ± 0.09 days for male and female respectively. The length and breadth of deutonymph was measured as 0.38 ± 0.03 and 0.24 ± 0.02 mm for female and male [8].

Teleiochrysalis: Teleiochrysalis also called as resting deutonymphal stage is the third and last resting stage. This stage showed shorter male and bigger female both were non-feeding, immobile and were with shiny dorsum. Teleiochrysalis stage was 0.62 ± 0.05 days for males and 0.77 ± 0.03 days for females (Table 1). The length and breath for male teleiochrysalis was measured as 347.59 ± 15.73 µm and 181.09 ± 9.45 µm; 472.10 ± 20.47 µm and 243.67 ± 12 µm for female respectively (Table 2). Earlier scientists reported teleiochrysalis period of 0.73 ± 0.11 and 0.92 ± 0.10 days for male and female respectively, while the length and breadth of teleiochrysalis was reported as 0.37 ± 0.02 and 0.26 ± 0.04 mm for female and male respectively [8].

Adults: Teleiochrysalis stage finally moults into adult stage. Both male and female had bright red eye spots on the dorsal propodosoma. Female mites were carmine red in colour, larger and plumper than male and with longer setae over the body and legs. Females became darker and broader after mating. Wavy markings were clearly visible on dorsal side. Adult female measured 499.12 ± 35.51 µm in length and 252.98 ± 8.74 µm in width (Table 2). Males were of bright reddish or orange coloured and smaller in size with tapering abdomen ends to a blunt point. First pair of legs was longer than fourth pair of leg, whereas second and third pair of leg was of same length. After emergence they were found wondering or waiting over the female quiescent stage i.e., female teliochrysalis for mating. Adult male measured 370.55 ± 16.28 µm in length and 165.49 ± 5.48 µm in width (Table 2). Previously the length and width of male were reported 0.42 ± 0.02 mm and 0.20 ± 0.01 mm respectively whereas, for female it was measured 0.49 ± 0.02 mm and 0.23 ± 0.01 mm in length and width respectively [7].

Total developmental period: The total developmental period i.e., egg to adult emergence was less in male (9.0 ± 0.17 days) in compare to female (10.32 ± 0.19 days) at 30.8-35.1^{0}C temperature and 64.5-74% relative humidity on okra (Table 1). Present results are in line with earlier workers. The total development duration of *T. macfarlanei* was reported 7.54 ± 0.94 days and 10.81 ± 0.65 days for male and female, respectively at 35^{0}C and 85 ± 3% relative humidity [9]. In *T. macfarlanei* the duration from egg to adult emergence was reported less in male (10.03 ± 0.55 days) as compared to female (11.22 ± 0.69 days) at 32^{0}C temperature and 85 ± 3% relative humidity [6]. Total duration from egg to adult emergence was reported less in male (9.67 ± 0.69 days) as compared to female (11.65 ± 0.77 days) in *Tetranychus macfarlanei* on cucumber leaflets at 25.00 ± 2^{0}C, 80 ± 5% relative humidity [7].

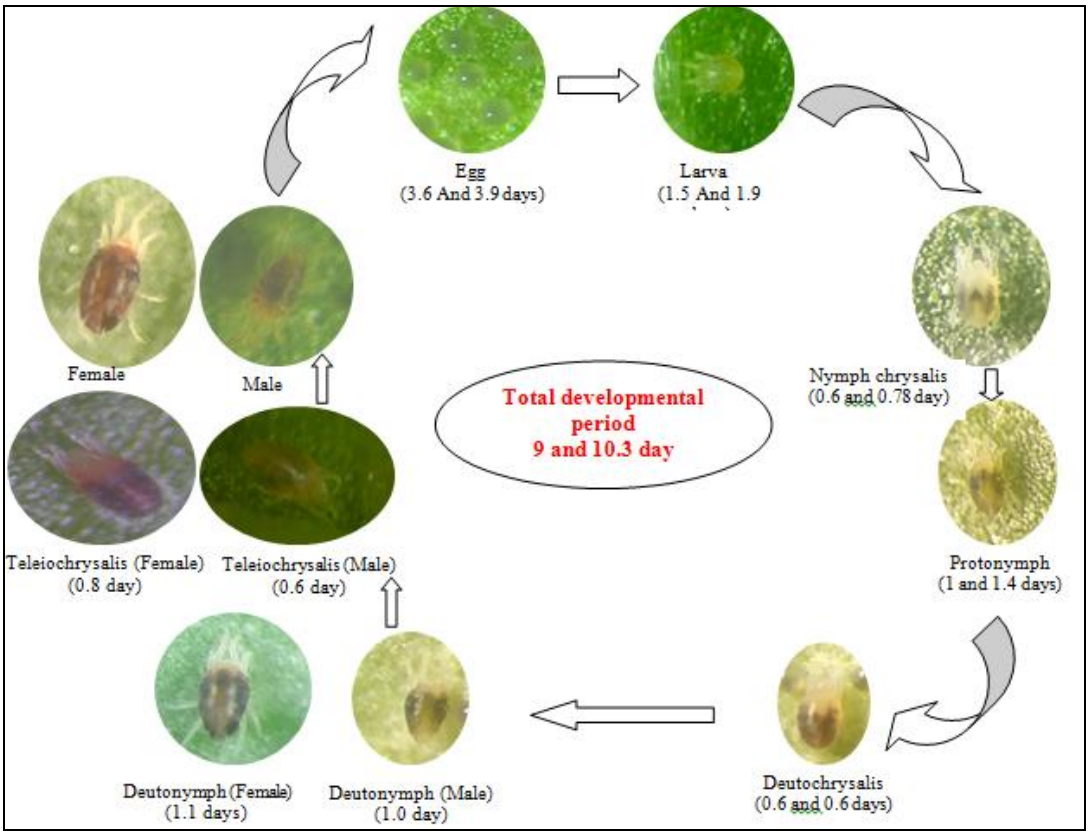

Plate 1: Life cycle of *T. macfarlanei* on okra

Reproductive biology of *Tetranychus macfarlanei*

Mating behaviour

Mating took place immediately after the female emergence. Soon after emergence of female, male pushed and raised the posterior abdominal region of the female and slides underneath the female with its hysterosoma upturned. The male held the female with its anterior pairs of legs in process of coupling. Mating lasted for a mean period of 1.26 ± 0.31 minutes. Previously many research workers has reported the similar mating behavior in *Tetranychus macfarlanei* [6, 7, 8].

Pre-oviposition, Oviposition and post-ovoposition period

The life span of adult female mites consisted of pre-oviposition period, oviposition period and post-oviposition period, which was observed longer in unmated female. The pre-oviposition period in mated and unmated females lasted for 0.95 ± 0.19 and 1.06 ± 0.40 days respectively. Oviposition and post-oviposition period lasted for 9.07 ± 1.70 and 1.66 ± 0.84 days respectively in case of mated female while 9.35 ± 1.43 and 2.03 ± 1.04 days respectively in case of unmated females (Table 3). Oviposition period is longer in females in compare to other life periods in its life cycle. Present results are in confirmation with [10] who reported oviposition period of 11.5 ± 0.38 days in mated female of *Tetranychus ludeni* on velvet bean at 30 ± 2^{0}C and 70 ± 5% relative humidity. Previous studies [6, 7, 8] confirms the longer oviposition period in unmated female in compare to mated female in *T. macfarlanei* with 15.92 ± 0.28 and 17.03±0.10 days on cucumber [7], 15.83 ± 0.16 and 17.92 ± 0.82 days on okra [6], 20.39 ± 1.27 and 22.17 ± 1.30 days on soybean [8] for mated and unmated females, respectively.

Table 3: Pre-oviposition, oviposition and post-oviposition periods in *T. macfarlanei*

Parameters	Duration (Mean ± S.D.)*	
	Mated	Unmated
Mating period	1.26 ± 0.31	----
Pre-oviposition period	0.95 ± 0.19	1.06 ± 0.40
Oviposition period	9.07 ± 1.70	9.35 ± 1.43
Post-oviposotion period	1.66 ± 0.84	2.03 ± 1.04

(* mean of ten observations)

Fecundity, egg viability and sex ratio in *Tetranychus macfarlanei*

Mated female of *T. macfarlanei* laid more eggs (52 ± 9.26) as compared to unmated female (33 ± 12) (Table 4). Similar results were reported earlier by many researchers. Mated and unmated females of *T. macfarlanei* was reported to laid 54.93 ± 8.08 and 31.87 ± 2.61 eggs respectively on soybean [8]. During the total oviposition period, it was reported that mated female of *Tetranychus macfarlanei* laid 50.23 ± 6.32 eggs, while unmated female laid 21.13 ± 4.89 eggs on cucumber leaflets at 25 ± 2^{0}C, 80 ± 5% relative humidity [7]. Egg viability in *T. macfarlanei* was recorded as 93.2 ± 1.17 percent in present study (Table 4). Previously, 89-96.5 percent egg viability was reported in *T. macfarlanei* on soybean [8]. Present study revealed a sexual as well as parthenogenetical arrhenotokous reproduction in *T. macfarlanei* which is a well known fact about Genus *Tetranychus* [6, 7, 8]. Mated female produced a progeny consisted of both male and female in the ratio 1: 4.14, whereas unmated female produced only males (Table 4). According to the earlier records male to female ratio was 1: 4.3 in *T. cinnabarinus* on marigold [11], 1:5.23 on cucumber [7], 1: 6.5 in *T. macfarlanei* on okra [12], 1: 9.6 in *T. macfarlanei* on soybean [8] and 1: 9.6 on okra [6].

Table 4: Fecundity, sex ratio and egg viability of *T. macfarlanei*

Parameter	Fecundity (No. of Eggs)	Male: female ratio	Egg viability (%)
Mated female*	52 ± 9.26 (range- 37-69)	1:4.14	93.2 ± 1.17
Unmated female*	33 ± 12 (range- 22-63)	1:0	

(* mean of ten observations)

Adult longevity of *T. macfarlanei*

Adult longevity for male was recorded 11.05 ± 0.99 days. Corresponding figures for mated female was 11.68 ± 1.68 days, while for unmated female adult longevity was found 12.45 ± 1.48 days. Male lived for shorter period of time than females (Table 5). Earlier reports suggested that the adult longevity of *T. macfarlanei* on soybean was 11.4 ± 0.7 days for male, whereas 24.6 ± 0.6 days for mated female [8]. In *T. urticae* the male lived shorter (10.1 ± 1.6 days) than the mated (13.4 ± 1.9 days) and unmated (10.8 ± 2.5 days) females [13].

Table 5: Adult longevity of *Tetranychus macfarlanei*

Sex		Adult longevity (Duration)	
		(Days ± SD)*	Range
Male		11.05 ± 0.99	9.8-12.6
Female	Mated	11.68 ± 1.68	9.29-15.21
	Unmated	12.45 ± 1.48	10.23-15.17

(* mean of ten observations)

Conclusion

T. macfarlanei showed short life cycle, parthenogenetical arrhenotoky and high fecundity at 30.8-35.1^{0}C temperature and 64.5-74% relative humidity which is the general range of temperature and relative humidity commonly prevailed at Vidarbha region. Their short development cycle tends to favor rapid development of pesticide resistance population by removing unfavorable genes for their existence. This may be an alert call for okra growers in Vidarbha region and there is a need to be prepared with management tactics in advance to avoid potential damage in okra crop system in future by this pest.

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