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Biology and life table of spider mite, *Tetranychus macfarlanei* baker and pritchard (Acari: Tetranychidae) on cucumber

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Abstract
The life history of *Tetranychus macfarlanei* Baker and Pritchard on cucumber leaflets was studied at 25.00 ± 2.00 ^{0}C, 80 ± 5 per cent R.H. Life table parameters of *T. macfarlanei* was conducted at four different constant temperatures, 20 ^{0}C, 25.3 ^{0}C (lab. temperature during June-December 2018), 28 ^{0}C and 32 ^{0}C on leaves of cucumber with 16h: 8h L:D conditions in a BOD incubator. The results indicated that the total duration from egg to adult emergence was less in male (9.67 ± 0.69 days) as compared to female (11.65±0.77 days). The adults of *T. macfarlanei* reproduced sexually and parthenogenetically. During the total oviposition period, mated female laid 50.23±6.32 eggs while unmated female laid 21.13±4.89 eggs. The total life cycle from egg stage till death of mite showed that the males completed life cycle earlier within 24.90±1.98 days while females required 31.40±0.98 days. There was higher survival rate for *T. macfarlanei* at lower temperature (20 ºC), as well as at moderate temperature (25.3 ºC) compared with highest temperature of 32 ºC and 28 ºC. An average fecundity of mated females was highest (53.20 eggs) at 28 ºC. The innate capacity of increase (r_m) and finite rate of increase (λ) of *T. macfarlanei* reached maximal values (0.123 and 1.131) at 32ºC. The mean generation time (T) and doubling time (DT) were shortest (12.31 and 2.43) at 32 ºC followed by 28 ºC (14.78 and 2.75) and longest (20.07 and 6.60) at 20 ºC. The net and gross reproductive rates were maximum at 28 ºC (40.97 and 55.22). The overall results suggested that *T. macfarlanei* could develop and reproduce within a wide range of temperatures. The range 28-32 ºC was the most suitable for the development, survival rate and reproduction of the spider mite.

Keywords: *Tetranychus macfarlanei*, biology, life table, cucumber

Introduction
The cucumber (*Cucumis sativus*) is an important vegetable crop commonly grown throughout India. The cucumber is native to northwest of India and has been cultivated for at least 3000 years in Western Asia. It is cultivated both as a summer and rainy season crop. India ranks 30th in global cucumber production and its total output of 1, 61,000 metric tons accounting for less than one per cent of the world's supply. Cucumber thrives in India's warm climate and they grow prolifically in the three southern states of Karnataka, Tamil Nadu and Andhra Pradesh. Karnataka grows 60 per cent of India's cucumbers, with the other two states accounting for 20 per cent each. Among different pests in polyhouse cucumber, the red spider mite (*Tetranychus macfarlanei* Baker and Pritchard) has been recognized as a serious pest. In Karnataka, it appeared in moderate to severe form on vegetables in and around Bangalore [1, 2].
The available literature indicates absence of biological life table studies of this mite on cucumber. Therefore, the present investigation was aimed to study life history and life table aspects of this mite on cucumber and to determine the effects of temperature and host plant on the growth, development and reproduction. The current study is the first report of life table of *T. macfarlanei* from Karnataka and on cucumber its first report from India and the results can be useful in pest management programme as well as to know the population dynamics of the mite.

Materials and methods
Biology of the *T. macfarlanei* Baker and Pritchard on cucumber Malini hybrid was studied under the Laboratory condition (25.00 ± 2.00 ^{0}C temperature and 80 ± 5 per cent RH),

Department of Agricultural Entomology, COA, Shivamogga during September 2016 at room temperature. T. macfarlanei infested leaves was collected as an initial culture from cucumber plants grown under polyhouse at COA, ZAHRS, Shivamogga. Ten gravid female mites were lifted carefully using camel hair brush from infested leaf and transferred to fresh cucumber leaf bit kept upside down on filter paper overlaying a wet cotton swab in Petri dish (15 cm diameter) and allowed to lay eggs overnight. Next day morning the number of eggs laid by these mites was counted and adults were removed from the leaf. After egg hatching, the newly emerged larvae were lifted carefully with the help of a moistened zero size camel hair brush and kept on leaf bits (2 cm X 2 cm) at the rate of one larva per leaf bit per Petri plate. Such 30 Petri plates were maintained to study the biology. The development of various stages of the mite was observed at 6 hr interval with the help of stereobinocular microscope. The leaf bits were replaced regularly to avoid leaf deterioration and consequent poor nutrition. The observation on life history included incubation period, larval period, protonymph, deutonymph, quiescent stages, pre-oviposition, oviposition and post oviposition periods, fecundity and longevity of adult were recorded. The morphometric parameters of different stages of mites like body length, body width, spermathecal calyx (spermatodactyl for male) and duplex setae were recorded with the help of a standardized occular micrometer fitted to a stereo binocular microscope.

Life table study of T. macfarlanei was conducted at four different constant temperatures, 200C, 25.30C (lab. temperature during June-December 2018), 280C and 320C on leaves of cucumber with 16h:8h L:D conditions in a BOD incubator. To assess life table parameters of T. macfarlanei on cucumber plant, one female and one male (for mating) were randomly selected from the stock culture and transferred to a fresh leaf disc (2 cm x 2 cm) placed on a water saturated cotton in a Petri dish (90 cm diameter). Female mites were allowed to lay eggs for 24 hours. For solitary rearing, newly deposited eggs of the same age were transferred singly, each to a leaf disc. Discs were examined twice in a day with the help of stereobinocular microscope and all biological aspects were recorded until the death of mite individuals.

Life table parameters and data analysis

Life table parameters including Intrinsic rate of natural increase (rm), Net reproductive rate (R0), Gross Reproductive Rate (GRR), Doubling time (DT), Finite rate of increase (λ) and Mean generation time (T) were computed with following method [3,4].

x (Pivotal age of the female)	Lx	mx	lxmx	x lxmx
1	l_1	m_1	l_1m_1	1 l_1m_1
2	l_2	m_2	l_2m_2	2 l_2m_2
3	l_3	m_3	l_3m_3	3 l_3m_3
	.	.	.	.
.	.	.	.	.
.	.	.	.	.
Σ x	Σlx	Σmx	Σ lxmx	Σ × lxmx

Where,

Lx = Proportion of females alive at age interval x

Mx = 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

Net Reproductive Rate, Ro (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 a sum of the products of lx and mx.

$Ro = \Sigma\ lxmx$

Mean Generation Time (T) (days) is the average age of parenthood, an accurate calculation of T is made by weighing each age by its total fecundity (lxmx) and dividing it by Ro.

T = (∑⁡[x lxmx])/R_o

Finite Rate of Increase in number (no. of female off-springs/female/day) (λ) was calculated using the formula,

λ = anti ln⁡ [(log_e R_o)/T]

Where, Ro and T are specifically defined

Intrinsic Rate of natural Increase/Innate Capacity for Increase in numbers, rm (no. of female off-springs/female/day) is the maximal rate of increase by the combination of food, temperature, quality of food, etc. rm was computed using the formula,

rm = ln (λ)

Where,

ln = Natural log

λ = Finite Rate of Increase in number

Doubling time = ln⁡2/(r_m)

Where,

ln = Natural log

rm = Intrinsic Rate of natural Increase

Taxanomic identification of cucumber mite (Tetranychus sp.)

For taxonomical identification of mite sp. from the collected specimen, some selected mite specimen were picked on tiny hair brush point and placed in centre of glass slide containing a drop of Hoyer's medium in such a way that all morphological characters necessary for identification can be clearly seen and covered with glass cover slip taking care that no air bubble was found during preparation of the slide with the help of stereobinocular microscope. The mounted specimens were kept in an oven at 40oC for seven to ten days and dried specimens were then labelled and numbered serially for identification. Identification of spider mite was made by sending out male and female mite to AINP on Agril. Acarology, UAS, GKVK, Bangalore. Infested leaf samples were used to support the identification process. Morphological characterization studies showed that the mite sp. identified was Tetranychus macfarlanei Baker and Pritchard

Results and Discussion

The mite T. macfarlanei passes through four active stages (larva, protonymph, deutonymph and adult) and four inactive stages viz., egg, nymphochrysalis, deutochrysalis and teleiochrysalis.

Egg

Freshly laid eggs were spherical in shape, smooth, translucent and appeared like a tiny water drop. As the eggs moved towards maturity they gradually turned to dull white, brownish and finally dark pinkish colour prior to hatching showing transparent and two red spot on egg surface corresponding to simple eyes of larvae. The egg measured 0.10 to 0.15 mm with an average of 0.12±0.01 mm in

diameter (Table 3). The period of incubation ranged from 2.60-4.50 days and 3.60-5.00 days with an average of 3.95 ± 0.69 days and 4.50±0.49 days in male and female, respectively (Table 1).

Table 1: Biology of spider mite, Tetranychus macfarlanei on cucumber under laboratory conditions

Stage	Sex	Developmental period in days	
		Range	(Mean ± SD)
Egg	Male	2.60-4.50	3.95 ± 0.69
	Female	3.60-5.00	4.50±0.49
Larva	Male	1.00-1.65	1.34 ± 0.28
	Female	1.20-2.50	1.80±0.36
Nymphochrysalis (Quiescent I)	Male	0.24-0.39	0.35 ± 0.04
	Female	0.30-0.51	0.48±0.17
Protonymph	Male	1.50-2.10	1.70 ± 0.20
	Female	1.80-2.20	1.98±0.12
Deutochrysalis (Quiescent II)	Male	0.45-0.52	0.49 ± 0.02
	Female	0.49-0.55	0.52±0.02
Deutonymph	Male	0.84-1.15	1.01 ± 0.13
	Female	1.00-1.50	1.35±0.14
Teleiochrysalis (Quiescent III)	Male	0.70-1.00	0.82±0.12
	Female	0.81-1.15	0.98 ± 0.15
Total Developmental period	Male	8.40-10.83	9.67 ± 0.69
	Female	9.53-12.70	11.65±0.77

Table 2: Life history parameters of adults of Tetranychus macfarlanei on cucumber under laboratory conditions

Period	Sex	Duration in days	
		Range	(Mean ± SD)
Pre oviposition	Mated female	1.40-2.00	1.68±0.20
	Unmated female	1.20-1.60	1.27±0.16
Oviposition	Mated female	15.23-16.20	15.92±0.28
	Unmated female	16.90-17.20	17.03±0.10
Post oviposition	Mated female	1.50-1.90	1.70±0.16
	Unmated female	1.90-2.28	2.15±0.17
Fecundity	Mated female	40.00-59.00	50.23±6.32
	Unmated female	12.00-24.00	21.13±4.89
Sex ratio (M:F)	Mated female	-	1:5.23
	Unmated female	-	1:0
Adult longevity	Male	12.85-17.70	15.23±1.71
	Female	18.68-19.83	19.31±0.37
Total life cycle	Male	21.60-27.46	24.90±1.98
	Female	29.13-32.87	31.40±0.98

The matured eggs were split vertically on one side of the cohesion from where larva widened this opening by pushing it apart with its legs and came out by leaving the egg shell intact on the leaf surface. Reports on egg period is not reported on cucumber, this is a first report but, egg period was reported in okra [5, 6], cotton [7, 8] and soybean [9], which is similar to present findings.

Larva

The newly emerged hexapod larvae were creamy white in colour and almost spherical to slightly oval in outline with two prominent red spots on the dorsal propodosomal region. The newly born larva crawled for some time immediately after hatching and later settled at a place for feeding on the cell sap. Initially freshly hatched larva was creamy white and finally turned to green after initiation of feeding for some time with dark specks appearing dorsolaterally. The body measured 0.14-0.17 mm with an average of 0.15±0.01 mm length and 0.09-0.12 mm with an average of 0.11±0.01 mm in width (Table 3). The male larval period ranged from 1.00-1.65 days with a mean of 1.34±0.28 days and that of female larval period ranged from 1.20-2.50 days with a mean of 1.80±0.36 days (Table 1). Generally larval period was shorter in male than female. These findings are confirmed by the results [5] on okra.

Nymphochrysalis (Quiescent I)

The mature larva entered in quiescent stage by webbing or anchoring itself to the leaf surface for assuming a characteristic pose in which the front two pairs of legs projecting forward and the hind pair projecting backwards were held close to the sides of opisthosoma. On an average, it measured 0.16-0.20 mm with an average of 0.18 ± 0.01 mm in length and 0.11-0.14 mm with an average 0.12±0.01 mm in width (Table 3). The male quiescent stage lasted for 0.24-0.39 days with mean of 0.35 ± 0.04 days and 0.30-0.50 days with mean of 0.48±0.17 days in female (Table 1). On contrary [10], reported quiescent stage of T. macfarlanei on okra was 0.54 ± 0.25 days and 0.66 ± 0.25 days for male and female, respectively during March and April month.

Protonymph

The protonymph was easily distinguished due to the presence of four pairs of legs and amber in colour when freshly formed. Two red spots were also observed on either side of cephalothorax. The length and width of protonymph was 0.19-0.23 mm with an average of 0.21±0.01 mm and 0.12-0.15 mm with an average of 0.13±0.01 mm, respectively (Table 3). The protonymphal period of male occupied 1.50-2.10 days with mean of 1.70 ± 0.20 days and female occupied 1.80-2.20 days with mean of 1.98±0.12 days, respectively (Table 1). These findings are supported by findings of [6], who reported protonymph period was 1.59± 0.32 and 1.79± 0.42 days in male and female, respectively on okra.

Table 3: Measurement of different stages of Tetranychus macfarlanei on cucumber

Stage	No. observed	Length (mm)			Width (mm)		
		Min.	Max.	Avg. ± SD	Min.	Max.	Avg. ± SD
Egg	10	0.10	0.15	0.12±0.01	-	-	-
Larva	10	0.14	0.17	0.15±0.01	0.09	0.12	0.11±0.01
Nymphochrysalis (Quiescent I)	10	0.16	0.20	0.18±0.01	0.11	0.14	0.12±0.01
Protonymph	10	0.19	0.23	0.21±0.01	0.12	0.15	0.13±0.01
Deutochrysalis (Quiescent II)	10	0.22	0.26	0.24±0.01	0.13	0.16	0.14±0.01
Deutonymph	10	0.30	0.37	0.34±0.01	0.16	0.18	0.16±0.01
Teleiochrysalis (Quiescent III)	10	0.35	0.40	0.38±0.01	0.16	0.20	0.18±0.01
Adult							
Male	10	0.37	0.46	0.42±0.02	0.18	0.22	0.20±0.01
Female	10	0.47	0.54	0.49±0.02	0.22	0.26	0.23±0.01

Deutochrysalis (Quiescent II)

As protonymph matured, it entered into second quiescent

stage by suspending all its activities of feeding, shrunken its body, legs with reduced size known as Deutochrysalis. The body measured 0.22-0.26 mm with mean of 0.24±0.01 mm in length and 0.13-0.16mm with mean of 0.14±0.01 mm in width (Table 3) and the life period existed 0.45-0.52 days with an average of 0.49 ± 0.02 days in male and 0.49-0.55 days with an average of 0.52±0.02 days in female (Table 1). These results are contrary to the findings [6] on okra, reported deutochrysalis stages in male ranged from 0.56 ± 0.20 days and that of female the period of stage ranged from 0.59 ± 0.22 days, respectively.

Deutonymph

The newly emerged deutonymph was larger and broader being more plumpy than the protonymph with quite noticeable sex determination period. Two red spots either side of cephalothorax were also visible in this stage. Sexual dimorphism became perceptible after the development of palps and claws on the first pair of the legs. In male addition to the pointed body is also smaller in size than female, it had light yellowish spots, while the female had dark grey spots. The length and width of deutonymph was 0.30-0.37 mm with an average of 0.34±0.01 mm and 0.16-0.18 mm with an average of 0.16±0.008 mm, respectively (Table 3). This stage lasted for 0.84-1.15 days with mean of 1.01 ± 0.13 days in male and 1.00-1.50 days with mean of 1.35±0.14 days in female (Table 1). Deutonymph period of T. macfarlanei on okra was 0.69 ± 0.52 and 0.60 ± 0.27 day for female and male, respectively and it measured 0.364 ± 0.02 mm in length and 0.203 ± 0.08 mm in width [10].

Teleiochrysalis (Quiescent III)

The matured deutonymph stage enters into a third inactive stage before it moulted into an adult stage known as teleiochrysalis. It remained inactive by anchoring itself to leaf surface. In this stage the body was shrunken and decreased in size having light carmine colour. The moulting of quiescent deutonymph resulted in the emergence of adult mite. It was measured 0.35-0.40 mm with an average of 0.38±0.01 mm in length and 0.16-0.20 mm with an average of 0.18±0.01mm in width (Table 3). The teleochrysalis period was 0.70-1.00 days with mean of 0.82±0.12 days in male while, 0.81-1.15 days with mean of 0.98 ± 0.15 in female (Table 1). These results are in line with the reports [6] on okra.

Total developmental period

The period of development of cucumber spider mite from egg to adult inclusive of quiescent period was 8.40-10.83 days with an average of 9.67 ± 0.69 days and 9.53-12.70 days with an average of 11.65±0.77 days for male and female respectively (Table 1). Total developmental period of T. macfarlanei was 10.03±0.55 and 11.23±0.69 days in male and female, respectively on okra [6] and 10.62 ± 0.69 and 11.92 ± 0.89 days in male and female, respectively on soybean [9]. On the contrary [10], found that this period for T. macfarlanei on okra as 5.69 ± 1.55, 4.30 ± 0.39 days for male and 6.13 ± 0.41, 5.07 ± 0.23 days for female during March- April and July- August, respectively and 6.4 ± 0.37 and 10.6 ± 0.56 days on *Clitoria ternatea* L. and *Justicia adhatoda* L., respectively [11].

Adult

The adults emerged from the skin of teleiochrysalis by splitting dorsally and started their activities immediately showing pronounced sexual dimorphism. The male emerged as an adult a bit earlier than females and were observed to rest near or on the top of teleiochrysalis or pharat female for her emergence. T. macfarlanei had long whip like chelicera and body setae in adult were few in number and arranged in transverse.

Male

The mature males had a narrow body with distinctly pointed abdomen and had two red spots corresponding to the simple eyes with reddish green body colour when newly emerged turning to pinkish as they get matured. Male aedeagus knob was very small with anterior and posterior projection. Males were smaller than the female. The first pair of legs was longer than the fourth pair while the second and third pairs were of similar in size but shortest. Male empodium II of T. macfarlanei comprised a small mediodorsal spur and three pairs of proximoventral hairs as on legs III–IV with hairs being shorter on empodium II. Males were rarely observed feeding and mostly found moving around or waiting near a quiescent female deutonymph (teleochrysalis). The average length and width of male were 0.37-0.46 mm with an average of 0.42±0.02 mm and 0.18-0.22mm with an average of 0.20±0.01 mm, respectively (Table 3). The male lived for 8.40-10.83 days with an average of 9.67 ± 0.69 days (Table 2). Male adult longevity of T. macfarlanei took 10.27± 0.47 days on brinjal [12] and recorded 11.37 ± 0.69 days on soybean [9] and 4.31 ± 0.88 days in okra and the body measured 0.362 ± 0.13 mm in length and 0.206 ± 0.005 mm in width [10].

Female

The newly emerged female was bright red in colour which after feeding changed to brick red with two red spots like simple eyes on the sides of dorsal propodosomal region with broad body and blunt posterior ends. *T. macfarlanei* female comprised three tactile setae in line with proximal duplex setae, the fourth tactile setae slightly proximal to the proximal duplex setal line. Female was measured 0.47-0.54 mm with mean of 0.49±0.02 mm and 0.22-0.26 mm with mean of 0.23±0.01 mm in length and width, respectively (Table 3). The mated female lived longer than male and unmated progeny with the range of 9.53-12.7 days on an average of 11.65±0.77 days (Table 2). Female longevity of T. macfarlanei on okra took 11.30 ± 3.62 days and the body measured 0.411 ± 0.01 mm in length and 0.243 ± 0.01 mm in width [10] and female longevity on brinjal as 11.89 ± 0.30 days [12]. Female lived longer (11.22 ± 0.69 days) than male (10.03 ± 0.55 days) in okra [6].

Mating

Mating between male and female usually took place soon after shedding of the last nymphal skin. Male usually emerged a little earlier than female and were observed wandering on the leaf surface and waited near quiescent female deutonymph for her emergence. Sometimes there was an aggressive fighting seen among three or four males themselves near the female by extending their chelicerae and pricking the other individuals. In the act of mating, the male crawled underneath the female from behind and raised the female opisthosoma slightly. Also males were found helping the adult female to emerge out by pulling off the exuvium from the posterior end of the female by its two anterior pair of legs. When it was succeeded the male immediately slide underneath the female with its hysterosoma upturned, then the female raised its posterior abdominal region to accommodate the male for

mating and male holding the female with first two pairs of legs. This coupling process lasted for about two to four minutes. Single male was observed to mate with several females, but a female usually mated only once soon after emergence and older females were occasionally preferred for mating by males. Almost similar mating behaviour has been reported [10, 6] on okra.

Sex ratio

Mated female produced progeny of both the sex, whereas unmated females invariably gave rise to male progeny. The spider mite, *T. macfarlanei* reproduced both bisexually and parthenogenetically (Arrhenotokously). The male to female ratio of bisexually reproduced population was worked out as 1:5.23, while the sex ratio of parthenogenetically reproduced population found to be 100 per cent male (Table 2). The sex ratio of T. macfarlanei as 6.5 females per male and parthenogenetically reproduced population gave 100 per cent males when reared on okra [10]. Male to female ratio was (1:9.6) on okra [6] and observed 1: 9.6 on soybean [9]; these results were contrary to the present findings.

Pre oviposition period

The mated and unmated female laid eggs only after a lapse of certain period. Pre-oviposition period was longer for 1.40-2.00 days with an average of 1.68±0.20 days and 1.20-1.60 days with an average of 1.27±0.16 days in mated female and 3.15 ± 1.20 days in unmated female. As the females fertilized immediately after emergence the pre copulation period was very negligible in case of mated females (Table 2), which is more or less similar with the report [6, 9].

Oviposition period

The egg laying period of mated and unmated females lasted for somewhat longer compared with its total developmental period. In case of mated females it took 15.23-16.20 days with mean of 15.92±0.28 days for laying eggs whereas unmated females required a little longer i.e., 16.90-17.2 days with mean of 17.03±0.10 days, respectively (Table 2), which is more or less in confirmation with the reports of [6]. On the contrary, observed oviposition period as 20.39 ± 1.27 and 22.17 ± 1.30 days in soybean for mated and unmated females, respectively [9].

Fecundity

During the total ovipositional period the average fecundity per mated female was 40.00-59.00 eggs with an average of 50.23±6.32 eggs and in unmated female the fecundity was 12.00 to 24.00 eggs with an average of 21.13±4.89 eggs (Table 2). The results are comparable with the findings of [13, 6] but differed with [14, 15]. The higher fecundity of T. macfarlanei has been reported by [7], who observed 137 eggs per female on cotton.

Post oviposition period

The post-ovipositional period lasted for 1.50-1.90 days with an average of 1.70±0.16 days and 1.90-2.28 days with an average of 2.15±0.17 days in mated and unmated females, respectively (Table 2). These findings are conformity with the reports of [5 6], but differed with the findings of [9] who reported 2.70 ± 0.20 days and 2.50 ± 0.28 days for mated and unmated female, respectively.

Total life cycle

The total life period occupied by T. macfarlanei varied from 21.60 to 27.46 days with an average of 24.90±1.98 days in male and 29.13 to 32.87 days with an average of 31.40±0.98 days (Table 2) in female at the room temperature during September–October, 2016. The total life period for male varied from 27.00 ± 0.81 days and 30.61 ± 0.82 days for female of T. macfarlanei on okra [6], respectively. Males took 21.99 ± 1.86 days and females took 36.53 ± 2.14 days to complete their life cycle on soybean [9].

The female longevity lasted for about 18.68-19.83 days with an average 19.31±0.37 days. The male lived for a period of 12.85-17.7 days with an average of 15.23±1.71 days (Table 2). Longer time was taken by unmated females to complete pre oviposition, oviposition and post oviposition period as compared to mated females these lines are similar to the findings of [2, 6] while differed with the studies of [9,10]. In the present findings the mated females laid more eggs than unmated females, similar results were found by [6].

Life table of Tetranychus macfarlanei on cucumber at different temperatures

Reproduction attributes and demographic parameters of T. macfarlanei at 20 ºC

Survival pattern (lx) of ovipositing female is shown in Fig. 1. Age specific fecundity (mx) data illustrated in Fig. 2 (Table 4), showed that egg laying by T. macfarlanei mated female on excised leaves of cucumber reached peak on the 13th days after its emergence. Mated and ovipositing females lived for a period of 22.20 days. Correspondingly, each female laid 41.27 eggs over a period of 18.62 days at 20 ºC. The corresponding male to female ratio in the resulting progeny was 1:8.1. Unmated females laid significantly less number of eggs i.e., 17.30 at 20 ºC.

Most important demographic parameter, Intrinsic rate of Natural Increase (rm) of spider mite estimated on cucumber leaves at 20ºC was 0.072 females offspring's per female per day. The number of female off springs per female per generation (R0) was 28.17 and Mean Generation Time and Doubling time were highest i.e., 20.07 and 6.60 days respectively, when reared at 20 ºC (Table 5).

Reproduction attributes and demographic parameters of T. macfarlanei at 25.3 ºC

Oviposition by mated females reached peak on the 10th days after its emergence. Mated females lived for a period of 20.20 days. Each female laid on an average of 48.27 eggs over a period of 16.85 days. Pre oviposition and post oviposition period was about 1.77 and 1.57 days, respectively. Male to female ratio in the resulting progeny was 1:4.9 (Table 4).

According to life table data generated from a cohort of 40 mated females, Mean Generation Time (T) of mite was 17.65 days. The Intrinsic rate of natural increase (rm) was 0.085 female's offspring's per female per day, while (R0) the number of female off-springs per female per generation was 32.30. The finite rate of increase (λ) was 1.089 (Table 5). The present findings are in confirmation with the findings of Sharma (2010) who studied the life table of T. macfarlanei on brinjal and he reported that at 25 ^{0}C the net reproductive rate (Ro) was 31.155, the mean generation time (T) was 17.448 days, the innate capacity for increase in numbers (rm) was 0.110 and the finite rate of increase (λ) was found to be 1.350.

Reproduction attributes and demographic parameters of T. macfarlanei at 28 ºC

Survivorship curve of T. macfarlanei female at 28ºC is as shown in Fig. 1 (Table 4). Each T. macfarlanei female laid an

average of 53.20 eggs over a period of 14.07 days. Female mites peak egg laying on 8th day (Fig. 2). Mated females lived for 17.45 days and produced progenies with the corresponding male to female ratio of 1:6.7. Virgin females laid relatively less number of eggs (25.17) as compared to mated females.

Intrinsic rate of natural increase (rm) of T. macfarlanei at 28ºC was 0.109 female off springs/female/day. The net reproductive rate (R0) was highest of 40.97 female off springs/female/generation. Mean Generation time (T) and Doubling Time of mite were 14.78 days and 2.75 days, respectively. The finite rate of increase (λ) was 1.115 (Table 5).

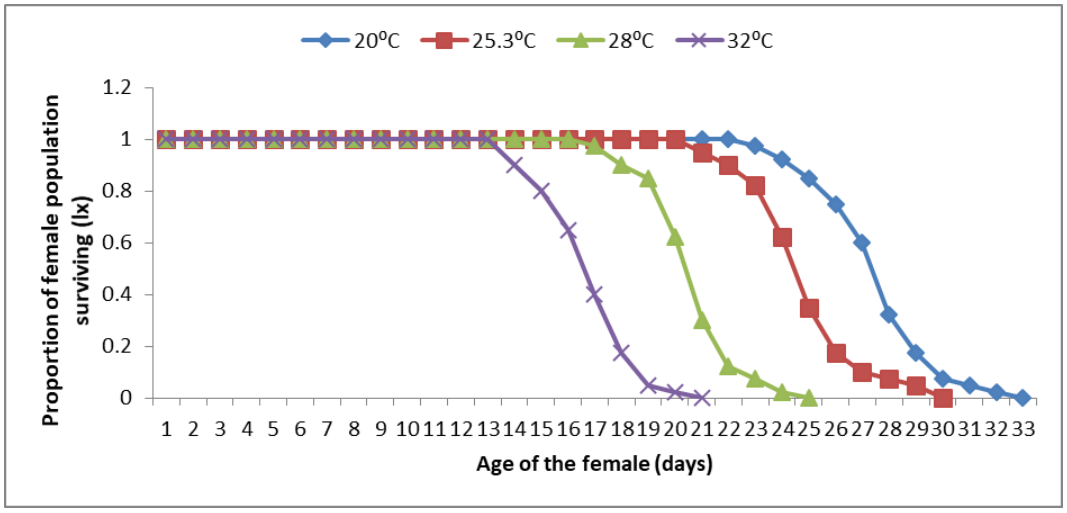

Fig 1: Age specific survival of Tetranychus macfarlanei reared on cucumber leaves at four different temperatures

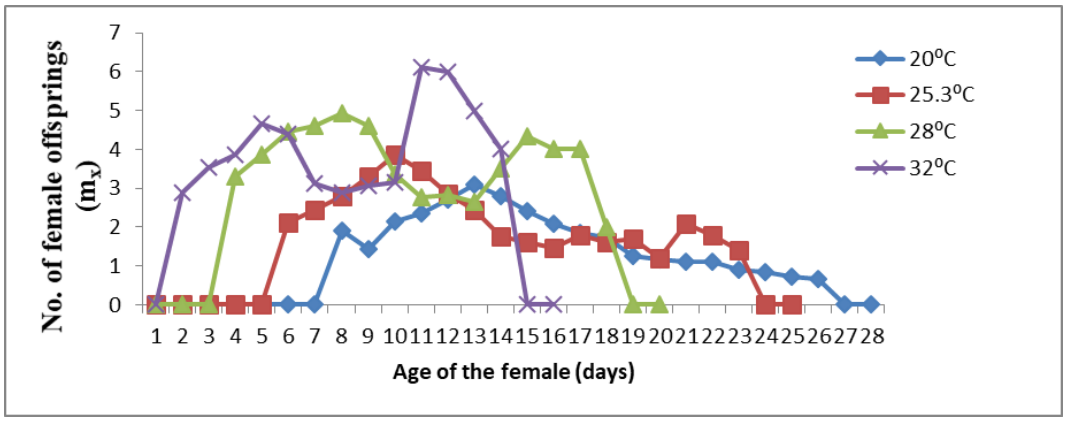

Fig 2: Age specific fecundity of Tetranychus macfarlanei reared on cucumber leaves at four different temperatures

Reproduction attributes and demographic parameters of T. macfarlanei at 32 ºC

Fecundity of T. macfarlanei (mx) reached maximum on 11th days after its emergence. On an average each female laid 47.22 eggs over oviposition periods of 11.30 days. The longevity of the female was 14.60 days and male to female ratio in the immediate progeny was 1:8.3 (Table 4).

Daily female production by a mated T. macfarlanei mother (rm) was highest i.e., 0.123 female off springs/female/day when it was reared at 32 ºC. Correspondingly, each mated female advanced its progeny (R0) with 33.42 daughters over a Mean Generation time (T) of 12.31 days. When cultured at 32ºC, mites Gross Reproductive Rate and finite rate of increase (λ) was 52.70 and 1.131 respectively.

As shown in Fig. 3, the survival rates of T. macfarlanei at four constant temperatures were different. There was a higher survival rate for T. macfarlanei at lower temperature (20 ºC), as well as at intermediate temperature (25.3 ºC) compared with highest temperature of 32 ºC and 28 ºC. The greatest reduction in survival rate for the spider mite took place at 32 ºC. An average fecundity of mated females was highest (53.20 eggs) at 28 ºC followed by 25.3 ºC (48.27 eggs) and 32 ºC (47.22 eggs). Lowest fecundity rate was observed at 20 ºC (41.27 eggs). There were two peaks each for mx curves at 28 ºC and 32 ºC and only one peak at 20 ºC and 25.3 ºC. Another point with regard to the mx curve is the fact that the lowest temperature (20 ºC) postponed the reproduction of T. macfarlanei until the 13th day after its emergence and intermediate temperature (25.3 ºC) postponed reproduction until 10th day after its emergence and thereafter, it produces two small peaks 17th and 21st day after its emergence (Fig. 2). The duration of oviposition periods were longer at 20 ºC and 25.3 ºC and fewer at 32 ºC. The male to female sex ratio was highest at 32 ºC (1:8.3) and 20 ºC (1: 8.1) and lowest proportion of female produced at 25.3 ºC (1:4.9). The duration of preoviposition period, oviposition period, longevity of male and females were decreased with rising temperature in the range of 20-32 ºC. Postoviposition period and fecundity of unmated females were increased with rising temperature (Table 4).

The innate capacity of increase (rm) and finite rate of increase (λ) of T. macfarlanei reached maximal values (0.123 and 1.131) at 32 ºC followed by 28 ºC (0.109 and 1.115), whereas minimal values (0.072 and 1.074) at 20 ºC. The mean generation time (T) and doubling time (DT) were shortest (12.31 and 2.43) at 32 ºC followed by (14.78 and 2.75) 28 ºC

and longest (20.07 and 6.60) at 20 ºC. The net and gross reproductive rates were maximum at 28 ºC (40.97 and 55.22) followed by (33.42 and 52.70) 32 ºC and minimum at 20 ºC (28.17 and 38.59). The overall results suggested that T. macfarlanei could develop and reproduce within a wide range of temperatures. The range 28-32 ºC was the most suitable for the development, survival rate and reproduction of the spider mite. The present findings are more or less similar to the findings of [12] who studied the life table of T. macfarlanei on brinjal and he also observed increasing trend of life table parameters with increase in temperature at constant relative humidity. The temperature range 24-31 °C was the most suitable for the development, survival rate and reproduction of Tetranychus truncates on mulberry leaflets [16].

Table 4: Reproduction parameters of Tetranychus macfarlanei reared on cucumber at four different temperatures

Temperature	Reproduction parameters									
	Pre-oviposition period (days)	Oviposition period (days)	Post oviposition period (days)	Longevity of mated female (days)	Longevity of male (days)	Mean no. of eggs/unmated female (n=40)	Mated female (n=40)			
							Mean no. of eggs/ female	Mean no. of female offsprings/ female	Mean no. of male offsprings/ female	Sex ratio of the progeny (♂:♀)
20 ºC	2.20	18.62^{a}	1.20	22.20^{a}	18.15	17.30	41.27^{c}	36.10^{c}	4.45	1:8.1^{a}
25.3 ºC	1.77	16.85^{b}	1.57	20.20^{b}	16.10	20.15	48.27^{b}	40.00^{b}	8.10	1:4.9^{c}
28 ºC	1.52	14.07^{c}	1.85	17.45^{c}	12.17	25.17	53.20^{a}	45.85^{a}	6.87	1:6.7^{bc}
32 ºC	1.32	11.30^{d}	1.97	14.60^{d}	8.32	29.32	47.22^{b}	41.80^{b}	5.05	1:8.3^{ab}

N.B.: Unmated female produced only male off springs; n: number observed;
Mean values within the column with different lower case alphabetical superscript are significantly different according to Tukey's HSD test (P<0.05)

Table 5: Demography of Tetranychus macfarlanei on cucumber at four different temperatures

Temperature	Demographic parameters (n=40)					
	Mean Generation Time (T) (days)	Doubling Time (DT) (days)	Net Reproductive Rate (R_0) (No. of female offsprings /female/generation)	Gross Reproductive Rate (GRR)	Finite Rate of Increase (λ) (No. of female offsprings/female/day)	Intrinsic Rate of Natural Increase (r_m) (No. of female offsprings/female/day)
20 ºC	20.07	6.60	28.17	38.59	1.074	0.072
25.3 ºC	17.65	3.52	32.30	46.37	1.089	0.085
28 ºC	14.78	2.75	40.97	55.22	1.115	0.109
32 ºC	12.31	2.43	33.42	52.70	1.131	0.123

The net reproductive rate (Ro) was the highest (37.39) at 24°C, followed by 37.00 at 31 °C. The innate capacity for increase (rm) and finite rate of increase (λ) reached maximal values (0.321 and 1.378) at 31 °C, whereas minimal values (0.134 and 1.143) were at 20 °C. The mean generation time was the shortest at 35 ºC and the shortest time for a population to double was 2.16 days at 31 °C.

On the contrary, T. macfarlanei was able to develop and complete its life cycle at temperatures ranging from 17.5 to 37.5 ^{0}C on kidney beans [17]. The net reproductive rate (R0) was highest at 250C (167.4 females per female) and lowest at 17.5 ^{0}C (42.6 females per female). The intrinsic rate of natural increase (rm), increased linearly with the rising of temperature from 0.102 at 17.5 ^{0}C to 0.441 day-1 at 35 ^{0}C.

Conclusion

Now a day's mites have been recognized as a serious pest causing damage to vegetables especially in protected condition, due to their phytophagous nature, high reproductive potential and short life cycle which contributes for rapid resistance development to many acaricides often after a few applications. Although spider mites form potential pests, very little is known about them. Understanding of their population dynamics as influenced by several subtle intrinsic and extrinsic factors demands detailed study. Hence to overcome this problem a new dimensional study was been undertaken to identify mite species and to work out the biology and life table of cucumber mites (*Tetranychus macfarlanei*) which may surely help for their effective management in both protected and field condition.

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