International Journal of Zoological Research

ISSN 1811-9778

Academic Journals Inc.

www.academicjournals.com

International Journal of Zoological Research 11 (3): 76-88, 2015
ISSN 1811-9778 / DOI: 10.3923/ijzr.2015.76.88

Biology and Demographic Parameters of European Red Mite, *Panonychus ulmi* Koch (Acari: Tetranychidae) on Mulberry in Kashmir Valley, India

[1,2]Mohd Yaqoob Dar, [1]R.J. Rao, [2,3]G.K. Ramegowda and [2]Vishal Mittal
[1]School of Studies in Zoology, Jiwaji University, Gwalior, 474011, Madhya Pradesh, India
[2]Central Sericultural Research and Training Institute, Central Silk Board, Pampore, 192121, Jammu and Kashmir, India
[3]Regional Horticultural Research and Extension Centre, University of Horticultural Sciences Campus, G.K.V.K. Post, Bengaluru, 560065, Karnataka, India

Corresponding Author: Mohd Yaqoob Dar, School of Studies in Zoology, Jiwaji University, Gwalior, 474011, Madhya Pradesh, India Tel: +918269278125, +919596195627

ABSTRACT

Life history traits of *Panonychus ulmi* on mulberry (*Morus multicaulis*) determined under ambient conditions; the temperature and relative humidity were same as that in natural conditions in three seasons of 2012. Developmental time from egg to adult for female and male varied from 12.66-23.24 and 10.62-18.65 days, respectively. Total and daily egg production was highest during summer (34.00 and 4.68 eggs, respectively) followed by spring (27.33 and 3.60 eggs) and lowest during autumn (17.80 and 1.87 eggs). *Panonychus ulmi* completed its life span in 19.07 and 21.76 days for male and female, respectively during summer and took more than one and half times during autumn. All parameters were intermediate during spring compared to highest during summer and least during winter. Intrinsic rate of natural increase (r_m) were 0.091, 0.147 and 0.051 day^{-1} during spring, summer and autumn seasons, respectively. Mean generation time (T_o) of the population ranged from 18.01 days during summer to 30.80 days during autumn. Based on the observed demographic parameters during three seasons, it is concluded that the summer season with average temperature of 25.72°C is highly favorable for development of *P. ulmi*.

Key words: Development, life history, *Morus multicaulis*, oviposition, *P. ulmi*, seasons

INTRODUCTION

Mulberry affords food and shelter for several organisms due to its perennial and luxuriant foliage. Pest infestation besides reducing the leaf yield, affects the feed value of mulberry leaf which is the principle food of silkworm *Bombyx mori* L. (Lepidoptera: Bombycidae). Reddy and Narayanaswamy (1999) reported more than 300 insect and non-insect species infesting one or the other part of the mulberry plant. Mites belonging to families of Tetranychidae and Eriophyidae cause leaf damage to the tune of 5-10% in India (Narayanaswamy *et al*., 1996).

The European red spider mite, *Panonychus ulmi* (Koch) (Acari: Tetranychidae) is polyphagous pest on a variety of crops and plants worldwide (Hardman *et al*., 1985). In India, *P. ulmi* has been recorded from peach, plum, apple, wheat, fig, hibiscus, tomato, apricot and ivy from Jammu and Kashmir (Kumar and Bhalla, 1993) but it has been reported for the first time as a serious pest of mulberry in the Terai zone of West Bengal, India (Karmakar *et al*., 1998). Dar *et al*. (2011) and

Ramegowda *et al*. (2012) have reported that mites are impairing the quality of mulberry leaves and cause adverse effects on the biological and economic parameters of silkworm fed on mulberry leaves infested by *P. ulmi*. The mite species damages are increasing day by day and consequent control costs rise linearly (Han *et al*., 2007; Qiu *et al*., 2012). Acaricides are being used most popularly in the mite management but in sericulture this can't be opted as acaricides will harm silkworm too besides, the side effects caused by them have been found to reduce antagonist diversity and development of acaricide resistance in *P. ulmi* strains.

In this background, studies were made to understand the population growth characteristics of *P. ulmi* and to see effect of seasonal changes of ambient conditions on developmental parameters of *P. ulmi* on mulberry in Kashmir valley. This study was aimed to get a platform for the control measures of this mite in mulberry plantation, which is the sole food for silkworm. The information on the population build up at various seasons will help to predict the pest load and initiate preventive and curative management measures to protect the mulberry leaf deterioration as well as protecting the silkworm from pesticide exposure.

MATERIALS AND METHODS

Studies were made at Central Sericulture Research and Training Institute, Central Silk Board, Gallandar, Pampore, Jammu and Kashmir, India located at 33°59'50"N latitude and 74°55'5"E longitudes and at an altitude of 1574 m above mean sea level on the bank of river Jhelum along the national highway 1A. All the experiments were carried out between May to October 2012. Studies were made during three seasons, spring with average daily temperature 19.89±2.95°C (13.26-24.75°C), summer 25.72±1.94°C (20.42-29.65°C) and autumn 15.69±4.75°C (8.20-24.36°C) (Lab. data).

Mass culture: Laboratory culture of *P. ulmi* was established from field collected mites on mulberry, well in the beginning of the season during April-May 2012. Adult females were identified under a stereoscope, transferred and maintained on fresh and clean mulberry leaves (5×5 cm) of Goshoerami variety *Morus multicaulis* placed on top of one cm thick moistened cotton and sponge pads in plastic trays (20 cm w×30 cm l×6 cm h). Cotton was watered as and when needed once or twice in a day to keep the leaves turgid depending on the season. The leaves were changed before signs of leaf deterioration at every two or three days. Sufficient mite colonies were maintained throughout the study period to ensure continuous culture supply. Leaves were examined every day to prevent over-population of mites. When over-population was encountered, the infested leaves were cut into small pieces and placed upon fresh leaves in a new tray. Temperature, relative humidity and photoperiod were monitored and recorded throughout the study period.

Immature development: In each experiment, twenty five gravid females from the mass culture were released individually on fresh leaf bits (4×4 cm) maintained in turgid conditions in glass petriplates (10 cm diameter) and allowed to lay eggs for 24 h. Eggs were lifted carefully with the help of moistened zero size camel hair brush and shifted on to fresh leaf bits (2×2 cm) at the rate of one egg per leaf bit on moistened cotton beds maintained in glass petriplates. Cotton beds were moistened with sufficient water once or twice a day to keep leaf bits in turgid condition besides avoiding mite from escaping. Such fifty plates for each season were maintained to study the biology. Development of various stages of mite was observed at 12 h interval with the help of stereo

binocular microscope (Leica® Wild M8). Leaf bits were replaced regularly to avoid leaf deterioration and consequent poor nutrition. Sex was identified in the teleiochrysalis stage and each teleiochrysalis female was provided with two adult males to ensure timely mating.

Reproduction and adult longevity: Newly emerged virgin females obtained from the first experiment were used to assess reproduction and longevity. Two sets of females viz., mated and unmated females were maintained to observe pre-oviposition, oviposition, post oviposition and fecundity (Osakabe *et al*., 1990; Patil, 2005; Hoque *et al*., 2008; Ullah *et al*., 2011).

Hatch rate, survival rate and sex ratio of offspring: Egg hatching rate, survival rate of immatures and proportion of female offspring were assessed under the same conditions mentioned above. These parameters were used to calculate age specific survival rate (l_x) and fecundity rate (m_x) during each season. Fifteen teleiochrysalis females for each season were placed individually with adult male on leaf discs (4×4 cm) of mulberry for copulation. Females were allowed to lay eggs for five days after pre-oviposition period. Eggs obtained from each female were kept to determine the above mentioned parameters after reaching adulthood (Gotoh and Gomi, 2003; Ullah *et al*., 2011, 2014).

Preparation of life table: The age-stage two-sex life tables were constructed considering the whole cohort (including females, males and individuals dying in immature stages) according to the method described by Chi (1988). Raw data of all individuals was analyzed in accordance with the age stage two sex life table theory (Chi and Liu, 1985) using the programme package TWOSEX-MS Chart. The age-stage specific survival rate (Sxj) (where x = age in days and j = stage), the age-specific survival rate (l_x), the age specific fecundity (m_x) and the population parameters (r_m, the intrinsic rate of increase; λ, the finite rate of increase; R_o, the net reproductive rate; T, the mean generation time and DT, population doubling time) were calculated accordingly. The intrinsic rate of increase was estimated by using iterative bisection method based on Euler-Lotka formula with age indexed from zero (Goodman, 1982):

$$\text{Intrinsic rate of natural increase } (r_m) = [\sum e^{-r(x+1)} l_x m_x = 1]$$

In the age-stage, two-sex life table, the l_x and m_x were calculated as:

$$l_x = \sum S_{xj}$$

$$m_x = \sum S_{xj} f_{xj} / \sum S_{xj}$$

The population parameters calculated were:

- **Gross Reproductive Rate (GRR):** Mean total number of eggs produced by a female over lifetime (GRR =$\sum m_x$) measured in eggs/individual
- **Net reproductive rate (R_o):** Total number of offspring that an individual could produce during its lifetime ($R_o = \sum l_x m_x$) measured in offsprings/individual (Tuan *et al*., 2014)
- **Finite rate of increase (λ):** Number of times the population will multiply itself per unit of time ($\lambda = e^{rm}$) measured in offspring/individual/day

- **Mean generation time (T):** The length of time that a population needs to increase to R_o fold of its size at the stable age-stage distribution and was calculated as $T = (\ln R_o)/r_m$, measured in days
- **Doubling time (DT):** Time required for a given population to double its number ($DT= \log_e 2/r_m$) measured in days

The Means and Standard Errors of the population parameters were estimated using the Bootstrap method (Huang and Chi, 2012). The graphs were plotted using Microsoft Excel 2007® application.

The mean temperature, relative humidity and light situations of ambient conditions observed in the laboratory varied with season and were as under:

- **Spring:** Average temperature 19.89±2.96°C, average relative humidity 66.49±7.23% and photoperiod of 14.16±0.27 h light and 9.84±0.27 h dark
- **Summer:** Average temperature 25.72±1.94°C, average relative humidity 75.08±6.25% and photoperiod of 13.82 h L and 10.18±h D
- **Autumn:** Average temperature 15.69±4.75°C, mean relative humidity 70.61% and photoperiod of 11.84±0.61 h L and 12.16±0.61 h D

Statistical analysis: Data on development of immature stages, life history parameters of adults, egg hatchability, immature survival rate and proportion of females (sex ratio) during different seasons were analyzed by factorial ANOVA and means were compared by Fisher's LSD test using MSTATC® software. Differences between sexes and mated and unmated females for various parameters were compared by Student t-test using MSTATC® software. Life table parameters were analyzed using the programme package, TWOSEX-MSChart for the age stage two-sex life table analysis (Version: 2015.016).

RESULTS

Development period of immatures of *P. ulmi*: Both the males and females of *P. ulmi* completed their developments successfully during all the given seasons although longer developments were observed during autumn. The immature developmental period of *P. ulmi* was significantly affected by seasons and differed with sex and mating. The period in females was three days longer (17.94 days) than males (14.75) (student's t-test, $p<0.05$, Table 1). Developmental time of each stage was significantly different between seasons as well as between male and female sexes (Fisher's LSD test, $p<0.05$, Table 1 and 2). Total developmental period regardless sexes were significantly shortest during summer (11.64) and longest during autumn (20.95) (Table 2). It took 12.66, 10.62, 17.92, 14.98, 23.25 and 18.65 days during summer, spring and autumn seasons, respectively for female and male (Table 1).

Hatch rate, survival rate and sex ratio of off-spring: Hatchability is the proportion of eggs hatched out of total number of laid eggs. Significant differences were observed among seasons during summer with the highest hatchability (79.89), followed by spring (70.34) and the least during autumn (56.60) (Fisher's LSD test at $p<0.05$, Table 3). Significantly highest survival of immatures was noticed during summer season (59.60%) followed by spring (41.60%) and least during autumn (25.79%). Proportion of females to male was higher during all seasons and it remained unaltered ranging from 67-69% females which dominated over males (Table 3).

Table 1: *In vitro* developmental biology of immature *Panonychus ulmi* on Goshoerami variety of mulberry during different seasons of 2012 in Kashmir valley

Parameters and sex	Duration (days) (Mean±SE)[1] Spring	Summer	Autumn	Mean	LSD value[2]	T-test
Egg incubation						
Female	6.93±0.14^{a}	4.99±0.15^{c}	7.22±0.17^{a}	6.38±0.79	0.3633	**
Male	5.98±0.47^{b}	4.47±0.10^{d}	6.31±0.09^{b}	5.59±0.57		
Larval period						
Female	3.12±0.15^{b}	1.48±0.09^{e}	3.73±0.14^{a}	2.78±0.67	0.3015	**
Male	2.26±0.07^{d}	1.35±0.08^{e}	2.63±0.09^{c}	2.08±0.38		
Nymphochrysalis						
Female	1.10±0.04^{c}	0.99±0.04^{cd}	2.01±0.11^{a}	1.37±0.32	0.1693	**
Male	1.02±0.03^{cd}	0.86±0.03^{d}	1.74±0.07^{b}	1.21±0.27		
Protonymph						
Female	2.30±0.12^{b}	1.52±0.09^{d}	2.96±0.11^{a}	2.26±0.41	0.3015	**
Male	1.84±0.06^{c}	1.13±0.05^{e}	2.32±0.16^{b}	1.76±0.35		
Deutochrysalis						
Female	1.16±0.09^{c}	1.05±0.06^{cd}	1.96±0.19^{a}	1.39±0.29	0.2665	**
Male	0.99±0.04^{cd}	0.84±0.04^{d}	1.48±0.06^{b}	1.08±0.20		
Deutonymph						
Female	2.24±0.10^{c}	1.69±0.09^{d}	3.03±0.13^{a}	2.32±0.39	0.2630	**
Male	2.08±0.07^{c}	1.15±0.05^{e}	2.76±0.10^{b}	1.99±0.47		
Teleiochrysalis						
Female	1.06±0.07^{c}	0.94±0.06^{cd}	2.34±0.17^{a}	1.45±0.45	0.2312	**
Male	0.86±0.03^{cd}	0.81±0.03^{d}	1.42±0.06^{b}	1.03±0.19		
Total developmental period						
Female	17.92±0.33^{b}	12.66±0.27^{d}	23.25±0.48^{a}	17.94±3.06	0.8214	**
Male	14.98±0.15^{c}	10.62±0.13^{e}	18.65±0.26^{b}	14.75±2.32		

[1]Means in a row superscripted with different letters are significantly different by Fisher's LSD test at p = 0.05, [2]Factorial ANOVA using MSTATC software, *Significant at p = 0.05, **Significant at p = 0.01

Table 2: Mean developmental biology of immature *Panonychus ulmi* on Goshoerami variety of mulberry, irrespective of sex in Kashmir valley

Parameters	Duration (days) (Mean±SE)[1] Spring	Summer	Autumn	LSD value[2]
Egg incubation period	6.46±0.47^{b}	4.73±0.26^{c}	6.77±0.46^{b}	0.2569
Larva	2.69±0.43^{b}	1.42±0.06^{c}	3.18±0.55^{a}	0.2132
Nymphochrysalis	1.06±0.04^{b}	0.93±0.07^{c}	1.87±0.14^{a}	0.1197
Protonymph	2.07±0.23^{b}	1.33±0.20^{c}	2.64±0.32^{a}	0.2132
Deutochrysalis	1.04±0.08^{b}	0.94±0.11^{b}	1.72±0.24^{a}	0.1884
Deutonymph	2.16±0.08^{b}	1.42±0.27^{c}	2.89±0.14^{a}	0.1897
Teleiochrysalis	0.96±0.10^{b}	0.87±0.06^{b}	1.88±0.46^{a}	0.1635
Total developmental period	16.45±1.47^{b}	11.64±1.03^{c}	20.95±2.31^{a}	0.5808

[1]Means in a row superscripted with different letters are significantly different by Fisher's LSD test at p = 0.05, [2]Factorial ANOVA using MSTATC software

Table 3: Selected life parameters of *Panonychus ulmi* reared on mulberry in Kashmir valley during 2012

Parameters (%)	Duration (days) (Mean±SE)[1] Spring	Summer	Autumn	LSD value[2]
Hatchability of eggs laid during first five days	70.34±1.92^{b}	79.89±1.90^{a}	56.60±2.03^{c}	5.550
Survival rate in immature	41.60±2.32^{b}	59.60±1.99^{a}	25.79±1.9^{c}	6.547
Proportion of females reached adulthood	67.30±2.10^{a}	67.07±1.99^{a}	69.44±4.79^{a}	8.314

[1]Means in a row superscripted with different letters are significantly different by Fisher's LSD test at p = 0.05, [2]Factorial ANOVA using MSTATC software

Life history parameters of adults: Sexual variation was distinctly visible at adulthood. Pre-oviposition, oviposition and post-oviposition periods, total fecundity and daily fecundity were significantly shortest in unmated females over mated females (Student's t-test, $p<0.05$, Table 4). Adult longevity was significantly higher in females than males (Fisher's LSD, $p<0.05$, Table 4).

Table 4: Life history parameters of *Panonychus ulmi* adults reared on Goshoerami variety of mulberry in Kashmir valley

Life history parameters ans sex	Mean±SE[1] Spring	Summer	Autumn	Mean	LSD value[2]	T-test
Pre oviposition (days)						
Mated	2.15±0.25^{bc}	1.43±0.10^{e}	3.03±0.18^{a}	2.20±0.46	0.4209	**
Unmated	1.75±0.11^{cd}	1.18±0.08^{e}	2.34±0.12^{b}	1.76±0.34		
Oviposition (days)						
Mated	8.14±0.58^{b}	7.43±0.26^{c}	9.76±0.43^{a}	8.45±0.69	1.154	**
Unmated	7.59±0.44^{bc}	6.69±0.18^{c}	8.37±0.44^{b}	7.55±0.48		
Post oviposition (days)						
Mated	1.90±0.18^{e}	1.57±0.11^{cd}	2.98±0.15^{a}	2.15±0.43	0.3829	**
Unmated	1.74±0.12^{cd}	1.37±0.11^{d}	2.32±0.15^{b}	1.81±0.28		
Adult longevity (days)						
Male	10.69±0.39^{e}	8.51±0.31^{d}	12.34±0.36^{b}	10.51±1.11	1.316	**
Female	12.19±0.75^{b}	8.91±0.40^{d}	15.77±0.48^{a}	12.29±2.80		
Total fecundity (nos.)						
Mated	27.33±2.02^{b}	34.60±1.03^{a}	17.80±0.85^{d}	26.58±6.87	3.576	**
Unmated	22.20±1.50^{c}	25.87±1.08^{b}	12.67±0.67^{e}	20.24±5.40		
No. of eggs/day/female (nos.)						
Mated	3.61±0.35^{bc}	4.69±0.14^{a}	1.87±0.11^{d}	3.39±1.15	0.5540	*
Unmated	3.35±0.16^{c}	3.93±0.21^{b}	1.54±0.08^{d}	2.94±0.98		
Total life span (days)						
Male	25.68±0.41^{c}	19.07±0.35^{e}	31.05±3.41^{b}	25.26±4.90	1.581	**
Female	30.53±0.88^{b}	21.76±0.40^{d}	39.72±0.82^{a}	26.39±7.34		

[1]Means in a row superscripted with different letters are significantly different by Fisher's LSD test at p = 0.05, [2]Factorial ANOVA using MSTATC software, *Significant at p=0.05, **Significant at p=0.01

Table 5: Mean life history parameters of *Panonychus ulmi* adults reared on Goshoerami variety of mulberry in Kashmir valley, irrespective of sex

Parameters	Mean±SE[1] Spring	Summer	Autumn	LSD value[2]
Pre oviposition (days)	1.950±0.14^{b}	1.30±0.06^{c}	2.68±0.09^{a}	0.298
Oviposition (days)	7.868±0.39^{b}	7.06±0.15^{b}	9.06±0.36^{a}	0.816
Post oviposition (days)	1.082±0.13^{b}	1.47±0.08^{c}	2.65±0.11^{a}	0.271
Adult longevity (days)	11.44±0.45^{b}	8.71±0.28^{c}	14.06±0.31^{a}	0.9303
Total fecundity (nos.)	24.77±1.70^{b}	30.20±0.81^{a}	15.23±0.51^{c}	2.528
No. of eggs/day/female (nos.)	3.480±0.18^{b}	4.31±0.12^{a}	1.70±0.06^{c}	0.392
Total life span (days)	28.11±0.48^{a}	25.05±0.28^{c}	30.74±0.44^{a}	1.118

[1]Means in a row superscripted with different letters are significantly different by Fisher's LSD test at p = 0.05, [2]Factorial ANOVA using MSTATC software

Pre-oviposition period lasted for 2.15 and 1.75 days during spring, 1.43 and 1.18 days during summer. While, it was 3.03 days and 2.34 days during autumn for mated and unmated females, respectively (Table 4). Irrespective of mating, it lasted for 1.95, 1.30 and 2.68 days during spring, summer and autumn seasons, respectively (Table 5).

The oviposition period was significantly longest during autumn (9.76 days for mated; 8.37 days for unmated) while, it was shortest during summer (7.43 and 6.69) (Fisher's LSD, $p<0.05$, Table 4). Irrespective of mating, oviposition period during summer season was shortest (7.06 days) followed by spring (7.87) and it was longest during autumn (9.06) (Table 5).

Post oviposition period varied with respect to seasons was significantly shortest during summer (1.57 and 1.37 days for mated and unmated, respectively) followed by spring (1.90 and 1.74) and the longest during autumn (2.98 and 2.32) (Fisher's LSD, $p<0.05$, Table 4). Irrespective of mating, post oviposition period was significantly longer during autumn (2.65) followed by spring (Table 5). The highest fecundity of *P. ulmi* was noticed in summer (34.60 by mated; 25.87 by unmated) against autumn (Table 4). Mated females recorded significantly higher fecundity (26.58) over

unmated ones (20.24) irrespective of seasons (Table 4) and were 24.77, 30.23 and 15.23 during spring, summer and autumn seasons, respectively which differed significantly from each other (Table 5).

Fecundity per day per female significantly differed between mated and unmated females (3.38 and 2.94 eggs) (Table 4). Daily egg production was highest during summer (4.69 mated; 3.93 unmated) and it was least during autumn (1.87 mated; 1.54 unmated) (Table 4). Irrespective of mating, daily fecundity was 3.48, 4.31and 1.70 eggs during spring, summer and autumn seasons, respectively (Table 5).

Males completed life span one day early (25.26 days) compared to females (26.39 days) which varied significantly during different seasons. *Panonychus ulmi* completed life span faster during summer (19.07 and 21.76 days, respectively for male and female) followed by spring compared to longest life span during autumn (31.05 and 39.72 days) (Table 4). Irrespective of sex, total life span of *P. ulmi* was the significantly shortest duration during summer (25.06 days) and longest during autumn (30.74) days (Table 5).

Life table for *P. ulmi*: All the determined parameters clearly depicted that *P. ulmi* preferred and performed well during summer followed by spring season over the autumn season. The values for the different life table parameters of *P. ulmi* are shown in Table 6.

The age stage-specific survival rate (S_{xj}) of *P. ulmi* during different seasons was the probability that a new born will survive to age x and stage j (Fig. 1). The newly laid egg survives to adult stage was highest during summer season than spring and autumn. The male adults emerged earlier, whereas, survived shorter than female during all the seasons (Fig. 1). The difference in l_x and m_x during three seasons (spring, summer and autumn) (Fig. 2) indicated summer as the most favorable season with the highest fecundity per day and shortest life span. The l_x curves showed highest age specific survival and shortest life span during summer and the least age specific survival and longest life span in autumn.

Highest GRR was observed during summer season (29.39 eggs/individual) followed by spring (20.19) and autumn (12.19) season (Table 6). Net reproductive rate (R_o) followed same decreasing trend as that of GRR with the seasons and it was the highest in summer (14.07 offspring/individual) followed by spring (9.23) and lowest in autumn (4.77). The intrinsic rate of population increase (r_m) was highest in summer (0.147 day^{-1}) followed by spring (0.091) and was lowest during autumn (0.051). Mean generation time (T) was significantly longer during autumn and spring than summer. Finite rate of increase (λ) during different seasons was 1.095, 1.158 and 1.052 (spring, summer and autumn respectively). The Doubling Time (DT) was least during summer (4.74 days) which almost doubled during spring (9.34 days) and was very high of nearly three folds during autumn (13.67).

Table 6: Life table parameters of *Panonychus ulmi* reared on Goshoerami variety of mulberry during different seasons of 2012 in Kashmir valley

Life table parameters	Spring	Summer	Autumn
GRR	20.190±3.13	29.390±3.704	12.190±4.17
R_o	9.230±2.36	14.070±2.96	4.770±1.93
r_m	0.091±0.12	0.147±0.01	0.051±0.14
T	24.370±0.53	18.010±0.46	30.800±0.98
λ	1.095±0.01	1.158±0.02	1.052±0.01
DT	9.34	4.74	13.67

GRR: Gross reproductive rate (eggs/individual), R_O: Net reproductive rate (offsprings/♀), r_m: Intrinsic rate of increase (day^{-1}), T: Mean generation time (days), λ: Finite rate of increase (day^{-1}), DT: Doubling time (days)

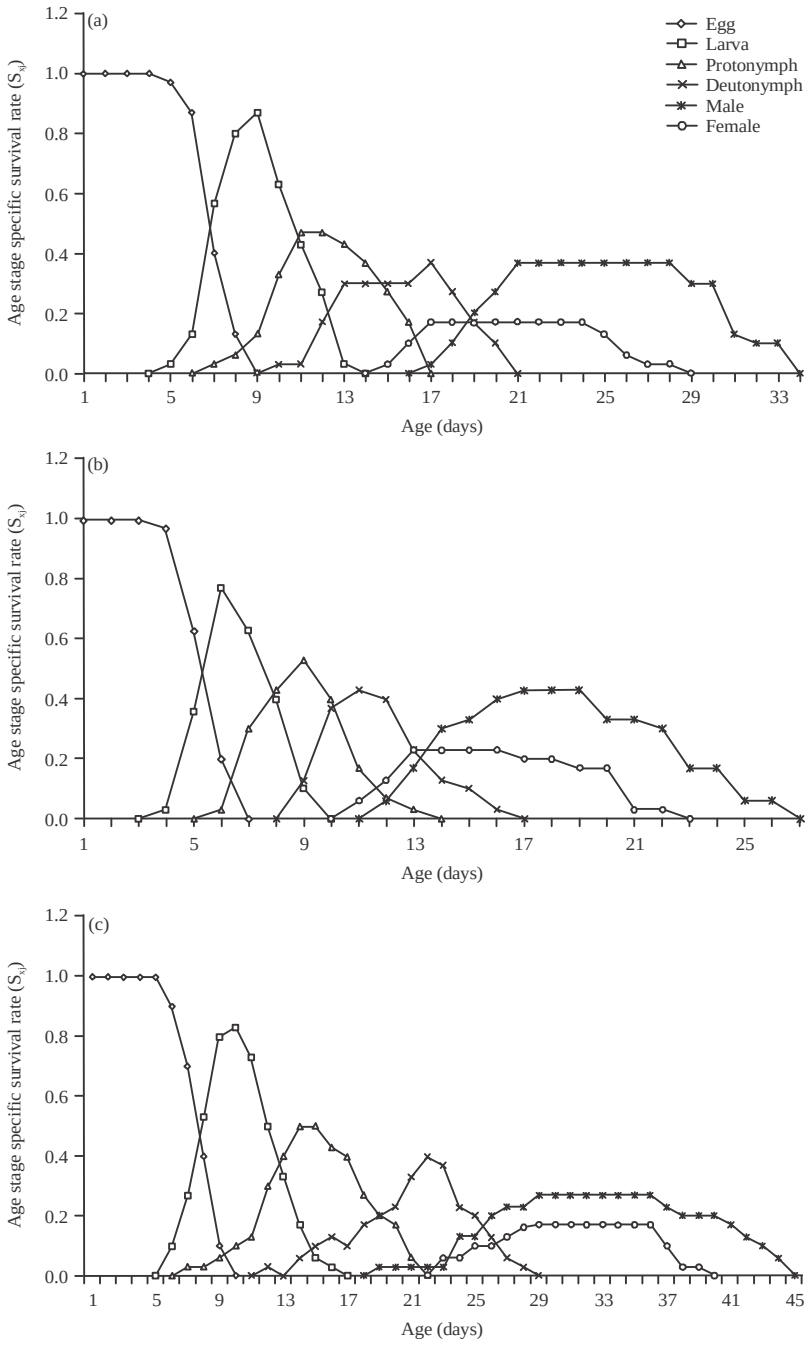

Fig. 1(a-c): Age stage-specific survival rate of *P. ulmi* reared during different seasons of 2012, (a) Spring, (b) Summer and (c) Autumn

DISCUSSION

Biology of *P. ulmi* under varied temperatures on different host plants has been well studied (Herbert, 1981; Osakabe *et al*., 1990; Karmakar *et al*., 1998; Khan and Sengonca, 2002; Gotoh *et al*., 2003). Present study on *P. ulmi* biology on mulberry with respect to seasons is the first of its kind. Mites have shown a well marked seasonal behaviour in their abundance and

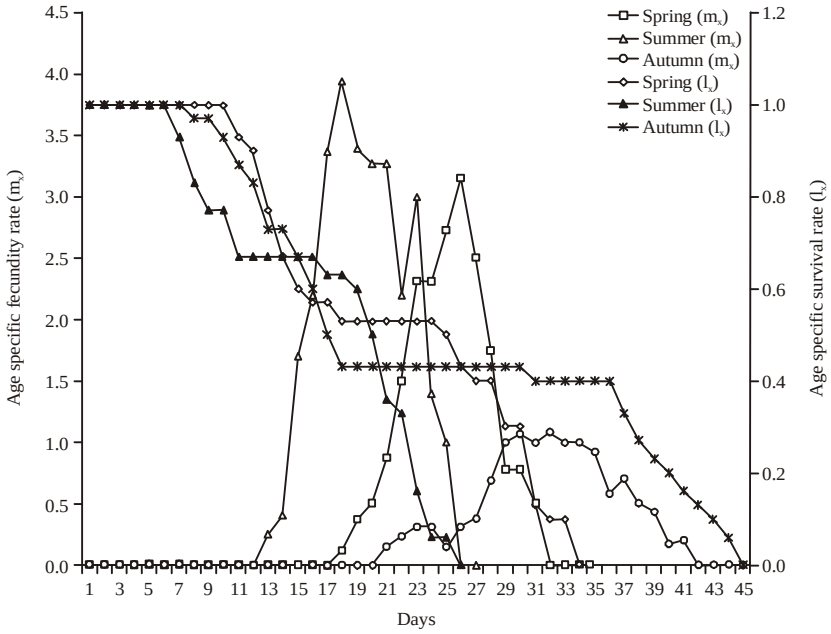

Fig. 2: Age specific survival rate (l_x) and age specific fecundity rate (m_x) of *P. ulmi* reared during different seasons

distribution on host plants. They are well adapted to seasonal climatic changes and such changes involve anatomical and behavioural changes (Narayanaswamy *et al*., 1996). However, decline in fecundity during the dry season or cold weather has been well documented (Das, 1959). Karmakar *et al*. (1998) reported that *P. ulmi* attain peak population during the second fortnight of March (19.74 mites/leaf) in mulberry gardens of West Bengal under subtropical climatic conditions.

In the present study, significant differences were observed between biological parameters of *P. ulmi* in three different seasons under temperate climate of Kashmir valley, India. *P. ulmi* developed successfully to the adult stage in all the seasons on *M. multicaulis*, however in autumn season the survival of immature was very low and all development periods were prolonged. All most all arthropod plant pests miss their survival during October to January in the temperate regions of northern hemisphere. These findings borrow support from Yin *et al*. (2013) who have reported that different apple varieties have a significant influence on the developmental time and reproduction of *P. ulmi*. Development duration from egg to adult has halved when temperature increased from 15-21°C. Developmental duration of males was shorter than that of females at all the temperatures studied (Herbert, 1981). In Kashmir valley, *P. ulmi* reached peak population by late July (mid-summer) to mid August (late summer) in abandoned and commercial apple orchards, respectively (Wani, 1999).

Total developmental duration from egg to adult emergence was longer in female (17.94 days) compared to male (14.75 days). Among seasons, during summer it was shortest (11.64) and longest during autumn (20.95), irrespective of sex. Studies of Karmakar *et al*. (1998) lend support to current findings, where in *P. ulmi* was dominant on mulberry during moderately warm and dry period of the year and has completed its total immature development period in a shorter time (9.10 days). The duration reported by Karmakar *et al*. (1998) are fairly shorter compared to the

durations recorded in present study, where the egg incubation period being distinctly more which may be due to macroclimatic variations, viz., subtropical and temperate climates. Developmental duration observed in the present study is in conformity with Khan and Sengonca (2002), who have reported a mean duration from egg to adult in *P. ulmi* on apple decreased from 18.1-12.8 days for females and from 17.9-12.2 days for males when the temperature increased from 25-30°C. The developmental duration of *Panonychus citri* (McGregor) on citrus ranged from nine to 37.2 days in temperatures ranging from 15-35±1°C (Kasap, 2009).

Highest survival of immature to the adulthood was recorded during summer (59.60%). This is very low and accounts for less than $2^{nd}/3^{rd}$ of the survival recorded at 25°C on mulberry (Osakabe *et al*., 1990) and apple (Khan and Sengonca, 2002) under controlled laboratory conditions. The difference may be due to difference in laboratory conditions, host plants and geographic difference between studies. Osakabe *et al*. (1990) used mulberry as laboratory host for *P. ulmi* collected on its preferred host plant, Pear and Kidney bean. It is also evident from the findings of Van den Boom *et al*. (2003) that, *T. urticae* does not accept all plants to the same degree due to difference in nutritive and toxic constituents, secondary metabolites and morphology of the leaf surface.

Sex ratio of *P. ulmi* remained almost the same throughout the study period spanning over three seasons, where in the females comprised 67.30, 67.70 and 69.44% during spring, summer and autumn seasons, respectively. This is supported by the findings of Kasap (2004) that, sex ratio of *Tetranychus urticae* did not differ significantly among temperatures. Contrary to this finding, Khan and Sengonca (2002) have reported change in sex ratio from 3:1 to 4:1 with change in temperature from 25-35°C. Such variations may be due to difference in temperature range, laboratory conditions, host and continuous light phase during rearing (24 h).

Hatchability of eggs ranged from 56.60-79.89% with highest during summer and least during autumn. More than 90% hatchability has been documented with *Tetranychus kanzawai* (Kishida) at 25°C (Gotoh and Gomi, 2003). Rani and Jandial (2009) reported highest egg hatchability in *Tetranychus cinnabarinus* during April- June (80.97%) and lowest during Mid Febuary-April (71.97%) which lends support to the present findings.

Studies confirmed that life history parameters in the adults of *P. ulmi* differed significantly with respect to season and those were significantly longer during autumn, followed by spring and shortest during summer. It is clearly evident that *P. ulmi* completed life faster during summer. Irrespective of sex, total life span of *P. ulmi* was significantly shortest during summer and longest during autumn. In findings of Herbert (1981) for *P. ulmi,* duration of pre-oviposition period decreased and number of eggs laid increased with increase in temperature also lend support to the present findings. Findings of Khan and Sengonca (2002) provide support to the present findings in reduction of mean duration of pre-oviposition period, oviposition and adult longevity of female and male *P. ulmi*. During present study, highest fecundity was noticed during summer as against a least during autumn. Daily egg production was highest during summer and was least during autumn. Khan and Sengonca (2002) observed reduction in mean total fecundity from 80-51 eggs per female and mean daily fecundity from 5.7-4.7 eggs per female with increase in temperature from 25-30°C. Kasap (2009) reported highest daily and total fecundity of *P. citri* at temperature of 25°C than other temperate tested and lends support to present findings. Ullah *et al*. (2014) reported that 70% reduction in the number of eggs may occur with host plant variation. Furthermore, strains collected from different geographical regions would show differences in life table parameters even when reared on the same host plant (Kondo and Takafuji, 1985; Razmjou *et al*., 2009).

Development time, oviposition rate and early peak in oviposition are important determinants of intrinsic rate of natural increase (r_m). Studies with spider mites have shown that, r_m is more dependent upon developmental time than oviposition rate when both values change at similar rates (Sabelis, 1985; Gotoh *et al*., 2003). Intrinsic rate of natural increase (r_m) and net reproductive rate (R_o) describe the growth potential of a population under specific climatic condition and reflect the overall effect of temperature on mite development, reproduction and survival. In the present study, both r_m and R_o, were higher during summer season than spring and autumn. The r_m obtained during summer season in the present study is comparable with that reported by Herbert (1981) at a temperature of 21°C. While the R_o during summer season was lesser than that reported at 15°C. Yasuda (1982) reported that 24°C was the most favorable temperature for the reproduction and development of *P. citri*. Present study revealed that in summer season GRR, R_o, r_m and λ being the highest. Generation time (T) and Doubling Time (DT) were shortest during summer followed by spring and longest during autumn. This was due the lower daily rate of offspring production and later peak in reproduction observed during autumn season. Kasap (2002) reported that at temperature of 24°C r_m, R_o and T of *P. citri* were 0.171, 28.3 females/female and 19.4 days, respectively. This difference may be attributed to difference in host plants, local population and time of year during when the studies were made. Two studies by Sabelis (1985, 1991) provide extensive information on the life history parameters of tetranychid mites. The r_m values of *T. kanzawai* reared on four different plants varied from 0.187 (tea) to 0.283 (mulberry) (Gotoh and Gomi, 2003). Studies clearly revealed that, all the developmental durations are shortest during summer besides higher survival making the quick pest buildup during summer season which was evident from the field pest populations (Dar *et al*., 2012a, b).

CONCLUSION

Study showed that summer in Kashmir valley is more favorable season for population build-up of *P. ulmi* on mulberry and affected the developmental time, especially egg duration and fecundity of that mite. Dynamic parameters of *P. ulmi* were too better during summer season under ambient conditions than autumn. Observations made under ambient laboratory conditions can be valuable in understanding population dynamics and informing pest management.

ACKNOWLEDGMENTS

Authors are thankful to University Grants Commission (UGC) New Delhi for providing the financial assistance under UGC Research Fellowship in Science for Meritorious Students Scheme (Fellowship No. F.4-1/2006 (BSR)/7-97/2007(BSR), 26, June, 2012). We are highly indebted to Jiwaji University, Gwalior and Director, CSR and TI, Pampore, J and K for providing all the support for present study.

REFERENCES

Chi, H. and H. Liu, 1985. Two new methods for the study of insect population ecology. Bull. Inst. Zool. Academia Sinica, 24: 225-240.

Chi, H., 1988. Life-table analysis incorporating both sexes and variable development rates among individuals. Environ. Entomol., 17: 26-34.

Dar, M.Y., I. Illahi, O.P. Agrawal, V. Mittal and G.K. Ramegowda, 2011. Impact of mite infestation on mulberry leaf and silkworm, *Bombyx mori* L. Indian J. Entomol., 73: 378-381.

Dar, M.Y., I. Illahi, O.P. Agrawal, V. Mittal and G.K. Ramegowda, 2012a. A preliminary study on mite damage assessment in mulberry. Munis Entomol. Zool., 7: 899-903.

Dar, M.Y., I. Illahi, O.P. Agrawal, V. Mittal and G.K. Ramegowda, 2012b. Preliminary studies on the mulberry mite diversity and dynamics in Kashmir. Indian J. Entomol., 74: 1-8.

Das, G.M., 1959. Bionomics of the tea red spider, *Oligonychus coffeae* (Nietner). Bull. Entomol. Res., 50: 265-274.

Goodman, D., 1982. Optimal life histories, optimal notation and the value of reproductive value. Am. Nat., 119: 803-823.

Gotoh, T. and K. Gomi, 2003. Life-history traits of the Kanzawa spider mite *Tetranychus kanzawai* (Acari: Tetranychidae). Applied Entomol. Zool., 38: 7-14.

Gotoh, T., Y. Ishikawa and Y. Kitashima, 2003. Life-history traits of the six *Panonychus* species from Japan (Acari: Tetranychidae). Exp. Applied Acarol., 29: 241-252.

Han, B.M., D.Y. Jin and L.S. Lu, 2007. Life table of *Panonychus ulmi* experimental population under different temperatures. Chin. Bull. Entomol., 44: 226-228.

Hardman, J.M., H.J. Herbert, K.H. Sanford and D. Hamilton, 1985. Effect of populations of the European red mite, *Panonychus ulmi*, on the apple variety red delicious in Nova Scotia. Can. Entomol., 177: 1257-1265.

Herbert, H.J., 1981. Biology, life tables and intrinsic rate of increase of the European red mite, *Panonychus ulmi* (Acarina: Tetranychidae). Can. Entomol., 113: 65-71.

Hoque, M.F., W. Islam and M. Khalequzzaman, 2008. Life table of two spotted spider mite *Tetranychus urticae* Koch (Acari: Tetranychidae) and its predator *Phytoseiulus persimilis* Athias-Heriot (Acari: Phytoseiidae). J. Bio. Sci., 16: 1-10.

Huang, Y.B. and H. Chi, 2012. Assessing the application of the jackknife and Bootstrap techniques to the estimation of the variability of the net reproductive rate and gross reproductive rate: A case study in *Bactrocera cucurbitae* (Coquillett) (Diptera: Tephritidae). J. Agric. For., 61: 37-45.

Karmakar, K., J. Ghosh and S.K. Senapati, 1998. Relative abundance and biology of European red mite *Panonychus ulmi* (Koch) (Acari : Tetranychidae) infesting mulberry cultivars. Environ. Ecol., 16: 101-104.

Kasap, I., 2002. Biology and life tables of two spotted spider mite, *Tetranychus urticae* (Acari: Tetranychidae) on three different host plants in laboratory conditions. Turk. J. Entomol., 26: 257-266, (In Turkish).

Kasap, I., 2004. Effect of apple cultivar and of temperature on the biology and life table parameters of the twospotted spider mite *Tetranychus urticae*. Phytoparasitica, 32: 73-82.

Kasap, I., 2009. The biology and fecundity of the citrus red mite *Panonychus citri* (McGregor) (Acari: Tetranychidae) at different temperatures under laboratory conditions. Turk. J. Agric. For., 33: 593-600.

Khan, I.A. and C. Sengonca, 2002. Laboratory investigations on development, longevity and reproduction of the European red mite, *Panonychus ulmi* (Koch) (Acari: Tetranychidae) at two high temperatures. Sharad J. Agric., 18: 331-333.

Kondo, A. and A. Takafuji, 1985. Resource utilization pattern of two species of tetranychid mites (Acarina: Tetranychidae). Res. Popul. Ecol., 27: 145-157.

Kumar, R. and O.P. Bhalla, 1993. An epidemic outbreak of *Panonychus ulmi* (Koch) (Acari: Tetranychidae) in apple orchards of Himachal Pradesh, India. Curr. Sci., 64: 709-709.

Narayanaswamy, K.C., M. Geethabai and R. Raghuraman, 1996. Mite pests of mulberry: A review. Indian J. Sericult., 35: 1-8.

Osakabe, M., S. Kobayashi and W. Ashihara, 1990. Development of the European red mite, *Panonychus ulmi* (Koch) (Acari: Tetranychidae), on mulberry and some other plants. Applied Entomol. Zool., 25: 326-328.

Patil, R.S., 2005. Investigations on mite pests of solanaceous vegetable with special reference to brinjal. Ph.D. Thesis, University of Agricultural Sciences, Dharwad.

Qiu, G.S., W.T. Yan, H.J. Zhang and Z.S. Zhou, 2012. The research on the dynamics and comprehensive control strategies of the main diseases and pests in the apple producing area of the *Bohai gulf*. Chin. Fruit, 3: 72-75.

Ramegowda, G.K., M.Y. Dar, V. Mittal, S.N. Ahmed and D. Guruswamy *et al*., 2012. Preliminary studies on the effect of mite damaged mulberry leaves on performance of silkworm, *Bombyx mori* L. Munis Entomol. Zool., 7: 926-930.

Rani, P. and V.K. Jandial, 2009. Comparative biology of carmine spider mite, *Tetranychus cinnabarinus* Boisduval (Prostigmata: Tetranychidae) infesting marigold. Indian J. Entomol., 71: 334-338.

Razmjou, J., H. Tavakkoli and M. Nemati, 2009. Life history traits of *Tetranychus urticae* Koch on three legumes (Acari: Tetranychidae). Munis Entomol. Zool., 4: 204-211.

Reddy, D.N.R. and K.C. Narayanaswamy, 1999. Present status of the thrips infesting mulberry. Indian J. Sericult., 38: 1-7.

Sabelis, M.W., 1985. Reproduction Strategies. In: Spider Mites-Their Biology, Natural Enemies and Control, Helle, W. and M.W. Sabelis (Eds.). Elsevier, Amsterdam, UK., pp: 265-278.

Sabelis, M.W., 1991. Life History Evolution of Spider Mites. In: The Acari Reproduction, Development and Life History Stragies, Schuster, R. and P.W. Murphy (Eds.). Chapman and Hall, London, UK., pp: 165-178.

Tuan, S.J., C.C. Lee and H. Chi, 2014. Population and damage projection of *Spodoptera litura* (F.) on peanuts (*Arachis hypogaea* L.) under different conditions using the age-stage, two-sex life table. Pest Manage. Sci., 70: 805-813.

Ullah, M.S., D. Moriya, M.H. Badii, G. Nachman and T. Gotoh, 2011. A comparative study of development and demographic parameters of *Tetranychus merganser* and *Tetranychus kanzawai* (Acari: Tetranychidae) at different temperatures. Exp. Applied Acarol., 54: 1-19.

Ullah, M.S., T. Gotoh and U.T. Lim, 2014. Life history of three phytophagous spider mites, *Tetranychus piercei*, *T. Truncates* and *T. Bambusae* (Acari: Tetranychidae). J. Asian-Pac. Entomol., 17: 767-773.

Van den Boom, C.E.M., T.A. Van Beek and M. Dicke, 2003. Differences among plant species in acceptance by the spider mite *Tetranychus urticae* Koch. J. Applied Entomol., 127: 177-183.

Wani, N.A., 1999. Studies on the response of various predators and pesticides to population of *Panonychus ulmi* (Koch). in Kashmir apple orchards. Ph.D. Thesis, Sher-E-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Jammu and Kashmir.

Yasuda, M., 1982. Influence of temperature on some of the life cycle parameters of the Citrus red mite, *Panonychus citri* (McGregor) (Acarina: Tetranychidae). Jpn. J. Applied Entomol. Zool., 26: 52-57.

Yin, W.D., G.S. Qiu, W.T. Yan, L.N. Sun, H.J. Zhang, C.S. Ma and U.P. Adaobi, 2013. Age-stage two-sex life tables of *Panonychus ulmi* (Acari: Tetranychidae), on different apple varieties. J. Econ. Entomol., 106: 2118-2125.