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Life and fertility table for female of mulberry silkworm, *Bombyx mori* Linn. race NB_4D_2 x SH_6 at different temperatures under laboratory conditions

Shani Kumar, Hem Singh and Pradeep Kumar Verma

Abstract
The study on the life and fertility table for the females of *Bombyx mori* Linn race NB_4D_2 x SH_6 were reared on mulberry plant variety S-1 leaves at two different temperatures *viz*,. Control temperature (25±1 °C) and room temperature in the lab of Sericulture Research, Demostration and Training Unit, Department of Entomology, College of Agriculture, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut-250110 (U. P.), India. The data obtained from the life and fertility table for female of *Bombyx mori* Linn race NB_4D_2 x SH_6 are exhibited highest potential fecundity was 331 eggs per female at control temperature (25±1°C) and 290 eggs per female at room temperature. The value of net reproductive rate (R_0), intrinsic rate of increase (r), finite rate of increase (λ) were 114.33, 0.07, 1.174 at control temperature (25±1 °C), respectively, much better than the values obtained from room temperature. The mean length of generation (T) and annual rate of increase were 27.66 days, 3.12437874 x 10^{28} at control temperature (25±1°C), respectively, also superior to the values obtained from room temperature.

Keywords: Life and fertility table for female, *Bombyx mori* Linn. race NB_4D_2 x SH_6, temperatures range, mulberry leaves *etc.*

Introduction
The mulberry silkworm, *Bombyx mori*' Linn. belongs to order Lepidoptera and family Bombycidae which has been considered as a reference in several domain. It is the most studied lepidopteran model system with a wide range of well characterized mutations affecting virtually every aspect of the organism morphology, development and behaviour. Mulberry silkworm undergoes complete metamorphosis and life cycle takes approximately 39-41 days. (Singh *et al*., 2020) [7]. India attains the 2nd position in silk production after China. In India, five known commercial varieties of silkworm *viz*., mulberry silkworm (*Bombyx mori* Linn.), Eri silkworm (*Samia Cynthia* Drury), Muga silkworm (*Antheraea assamensis* Helfer), Tropical silkworm (*Antheraea mylitta* Drury) and Oak tasar silkworm (*Antheraea proylei* Jolly) are cultivated (Joy Oomman, 2004) [5].
The construction of life tables is an important tool for understanding the population dynamics of an insect. Life and fertility tables serve as a framework for organizing data on age and reproductive stages of an insect. Additionally, it provides a detailed transparent description of the actual properties of the cohorts (Carey, 2001) [9]. The life and fertility table for female is a concise summary statement for net reproductive rate (R_0), Mean length of generation (T), intrinsic rate of increase (r), Finite rate of increase (λ), Potential fecundity (pf), Doubling time (Dt) and Annual rate of increase (ARI). Realizing the importance of the mulberry silkworm, *Bombyx mori* Linn.race NB_4D_2 x SH_6 as a beneficial insect an effort was made to construct the life and fertility table for female at different temperatures *viz*., control temperature (25±1°C) as well as room temperature.

Materials and Methods
The studies on various aspects of mulberry silkworm. Eggs of mulberry silkworm were brought from silkworm egg production unit, State Sericulture Farm, Kanker Khara, Meerut, (U.P.). The culture of mulberry silkworm was maintained in the Sericulture Research, Demostration and Training Unit, Department of Entomology, College of Agriculture, Sardar

Vallabhbhai Patel University of Agriculture and Technology, Meerut on mulberry leaves (Var. S-1). Soft and tender chopped mulberry leaves were provided to the worm during rearing. The eggs sheet could be kept in dark and cool condition. On the day of pin head or blue egg stage, all eggs are covered with a black paper known as black boxing, facilitate to fast development of embryo and uniform hatching. The mulberry silkworm's larvae were kept in plastic trays size (90 cm x 70 cm x 10 cm) for feeding. In order to maintained humidity a layer of wet filter paper (Ordinary lab quality) was placed in the bottom of plastic trays. The trays were covered with muslin cloth. Fresh chopped mulberry leaves were provided 3 times in a day to the mulberry silkworm till the maturity of larvae and proper hygienic conditions were maintained in the rearing room because mulberry silkworms are very prone to various microbial diseases like Pebrine, Flacherie, Grassaerie and Muscardine *etc*. When the mulberry silkworms attained full growth and stop feeding than, it was transferred to the montages fitted trays for the cocoon's formation at the rate of 40-45 larvae per fit^2. After all the mulberry silkworms have completed cocoon formation which took normally 5 to 7 days, the harvesting was done after 3-4 day of cocoon formation and the freshly harvested cocoons were kept in small boxes whose top was covered with muslin cloth for adult emergence.

Disinfection

Disinfection was done before rearing of mulberry silkworm. The Sericulture Research, Demonstration and Training Unit, including all the rearing equipments were disinfected with 4 per cent formaldehyde solution and closed the lab for 24 hours after spray of solution to destroy pathogens and eggs of insect pests and remove the infection of microorganism like Bacteria, Virus Fungi and Protozoa *etc*. The eggs sheet dipped in 2 per cent formaldehyde solution for 5 minutes for disinfection. Thereafter, the egg sheet was thoroughly washed in tap water and dried in air. After those eggs were ready for incubation and placed in BOD at control temperature (25±1°C) as well as room temperature for uniform hatching.

Ten female adults were randomly collected from different age group and allow for mating with male of same age group from the respective breed of mulberry silkworm for construction of life and fertility table for female. Pairing of male and female was done in separate petri dishes containing a sheet of moist filter paper. The counting of eggs was done daily in order to check the fecundity of female. During this period, no food was given to adults because they have vestigial type of mouth part.

The life span of individual adult was also recorded. This method was employed for construction of life and fertility table for female of the mulberry silkworm, *Bombyx mori* Linn. Species taken in the experiment for detail study of every aspects of life parameters. The following three different life tables were constructed under lab condition.

Life and fertility table for female of mulberry silkworm, *Bombyx mori* Linn.

The life specific survival and fecundity table for female of mulberry silkworm was constructed with the following assumptions:

A. The survivorship rates will be assumed to the same for the both sexes, as it will not possible to identify the sexes prior to the adult stage.
B. The sex could not be identified at the egg stage, therefore, a sex ratio of 1:1 will be considered in each batch of eggs.

This table was constructed on the suggestions made by Birch, 1948 [3] which consists the following columns:

x= Pivotal age of the class in days

l_x= No. of female live at the beginning of the age interval x (as fraction of initial population of one).

m_x= Average number of female eggs laid per female in each age interval assuming 50:50 sex ratio and is computed as:

$m_x = N_x/2$

Where

N_x = Total natality per female offspring in each age.

m_x= Total number of female eggs laid in age interval x. ($l_x.m_x$) was also calculated by multiplying the column lx and m_x termed as "Reproductive expectation".

The various numbers of parameters were computed from the age specific survival and fertility life table of female which includes following:

Net reproductive or replacement rate (R_0)

It is also known as "carrying capacity" of the average an insect under certain environmental conditions. The information on the multiplication rate of the population of one generation is obtained from it. It is represented as,

$R_0 = l_x.m_x$

Mean length of generation (T)

The mean length of generation is defined as the mean period between the birth of parent and the birth of their progeny. The period is a weighed approximate value, since the progeny is produced over a period of time and it is not a definite time, the calculation followed the method as suggested by (Lota and Dubin, 1925) [4].

$T=l_xm_x.x/l_xm_x$

Intrinsic rate of increase (r)

It is also represented by "r"or "r^m" or "r^{max}" and referred to as biotic potential. It is defined as the quick rate of increase of a population per unit time under set of ecological conditions **(**Birch, 1948) **[3]**. A rough estimate of the intrinsic rate of increase (r) can be calculated using the following equation: -

$r = (\log_e R_0)/T$

Where

$R_0 = l_x.m_x$

'T' represents mean length of a generation for an accurate estimate of 'r' (Birch, 1948) [3] introduced some approximation to the method in order to minimize the experimental errors in the formula suggested by Dubin and

Lotka, 1925 [4] and given as under;

$\sum e^{-rx} l_x m_x . d_x = 1$ (Lotka, 1925) [4]

$\sum e^{-rx} l_x m_x = 1$ (Birch, 1948) [3]

Finite rate of increase (λ)
It gives the information about the frequency of the population multiplication in a unit of time (Birch, 1948) [3].
It denoted as $(\lambda) = e^r$, by multiplying with $\log_e$ to both sides, we get,

$\log_e = \log_e e^r$

λ = Antilog e^r

This was used for computing the rate of increase of population per year.

Potential fecundity (PF)
Potential fecundity shows that the total number of eggs laid on an average by female in her life span. It is obtained or calculated by adding up the age specific fecundity column.

$Pf = \Sigma m_x$

Doubling time (DT)
It is referred as the time required for the population to get double and is calculated by the following equation:

$DT = Log_e 2/r$

Annual rate of increase (ARI)
Annual rate of increase can be calculated from intrinsic rate of increase (r) or finite rate of increase (λ) or doubling time (Dt) or the net reproductive rate (R_0) assuming that the rate of increase was constant throughout the year.

$ARI = 365 = e^{365r} = 2^{365/DT} = R0^{365/T}$

Results and Discussion
The data for life and fertility table for female of *Bombyx mori* Linn. race NB_4D_2x SH_6 was computed and have been summarized in the table-1, 2 and 3.

Age specific female's survivorship
The table- 1 and 2, indicated that the female starts oviposition, the maximum female survivorship 0.37 was recorded at control temperature (25±1 °C), while minimum female survivorship 0.27 was recorded at room temperature of *Bombyx mori* Linn. race NB_4D_2 x SH_6.

Rate of fecundity
It is evident from the table-1 and 2, the female of *Bombyx mori* Linn. starts egg laying in 33rd day at control temperature (25±1 °C) and 36th day at room temperature in hybrid cross NB_4D_2 x SH_6 of *Bombyx mori* Linn.
An interesting feature was noticed that the female laid its eggs during a definite period of pivotal age of hybrid cross NB_4D_2 x SH_6 of *Bombyx mori* Linn. in both conditions *viz*., control temperature (25±1 °C) as well as room temperature. The data also revealed that the duration of egg laying period was 4 days in all cases of hybrid cross NB_4D_2 x SH_6 of *Bombyx mori* Linn. The peak activity of egg laying was encountered between 33rd to 36th days at control temperature (25±1 °C). In case of room temperature, the peak activity of egg laying was encountered between 36th to 39th days in *Bombyx mori* Linn. Race NB_4D_2 x SH_6.
Other life parameters were also computed while constructing female fertility table which have been summarized in Table 3 and parameters includes under:

Potential fecundity ($\sum m_x$)
It is evident from the table-3, that there was a marked variation in the potential fecundity with respect to hybrid cross of *Bombyx mori* Linn race NB_4D_2x SH_6. The highest value of potential fecundity 331was recorded at control temperature (25±1 °C) followed by 290 at room temperature in NB_4D_2 x SH_6 hybrid cross of *Bombyx mori* Linn

Net reproductive rate ($l_x m_x$)
It is evident from the table-3, the highest value of net reproductive rate ($l_x m_x$) 114.33 was recorded at control temperature (25±1 °C) followed by 85.06 at room temperature in *Bombyx mori* Linn. race NB_4D_2 x SH_6.

Mean length of generation (T)
It is evident from the table-3, the highest value of mean length of generation (T) 37.92 days recorded at room temperature and 27.66 days at control temperature (25±1 °C) in hybrid cross of *Bombyx mori* Linn. race NB_4D_2 x SH_6.

Intrinsic rate of increase(r)
It is evident from the table-3, the highest value of intrinsic rate of increase (r) 0.07 was recorded at control temperature (25±1 °C) followed by 0.05 at room temperature in hybrid cross of *Bombyx mori* Linn. race NB_4D_2 x SH_6.

Finite rate of increase (λ)
It is evident from the table-3, the highest value of finite rate of increase (λ) 1.174 was recorded at control temperature (25±1 °C) followed by 1.122 at room temperature in hybrid cross of *Bombyx mori* Linn. race NB_4D_2 x SH_6.

Doubling time (DT)
It is evident from the table-3, there was a marked variation in the values obtained for *Bombyx mori* Linn. race NB_4D_2xSH_6 at control temperature (25±1 °C) and room temperature which were 4.30 and 6.02 days, respectively.

Annual rate of increase (ARI)
It is evident from the table-3, variation in the values obtained for annual rate of increase in the hybrid crosses of *Bombyx mori* Linn. race NB_4D_2 x SH_6. The maximum annual rate of increase (ARI) $3.12437874527 \times 10^{28}$ was recorded at control temperature (25±1 °C) and $3.75512635083 \times 10^{18}$ at room temperature.
The observation recorded and obtained from life and fertility table for female of *Bombyx mori* Linn. The peak activity of egg laying of female of *Bombyx mori* Linn. race NB_4D_2 x $SH_6$was encountered between 33rd to 36th day at control temperature (25±1 °C). In case of room temperature, the peak activity of egg laying of female of *Bombyx mori* Linn. race NB_4D_2 x SH_6 was encountered between 36th to 39th day. The

highest value of potential fecundity 331was recorded at control temperature (25±1 °C) followed by 290 at room temperature. The highest value of net reproductive rate (l_x m_x) 114.33 was recorded at control temperature (25±1 °C) followed by 85.06 at room temperature. The range of mean length of generation required by *Bombyx mori* Linn.race NB_4D_2 x SH_6 was 37.92 days at room temperature and 27.66 days at control temperature (25±1 °C).The highest value of intrinsic rate of increase (r) 0.07 was at control temperature (25±1 °C)followed by 0.05 at room temperature in hybrid cross of *Bombyx mori* Linn. race NB_4D_2 x SH_6.The highest value of finite rate of increase (λ) 1.174 was recorded at control temperature (25±1 °C) followed by 1.122 at room temperature in hybrid cross of *Bombyx mori* Linn.race NB_4D_2 x SH_6.The doubling time was also concerned, there was a marked variation in the values obtained for *Bombyx mori* Linn.race NB_4D_2x SH_6 at control temperature (25±1 °C) and room temperature were 4.30 and 6.02 days, respectively. The maximum annual rate of increase 3.12437874527 x 10^{28} was recorded at control temperature (25±1 °C) and 3.75512635083×10^{18} at room temperature.

These findings partially similar to findings of Vakhide *et al*., 2014 [8] revealed that the intrinsic rate of increase (r) was 0.313 ± 0.0019 females per day and the finite rate of growth (λ) was 1.36 ± 0.0027 females per female per day of green bug, *Schizaphis graminum*. The net reproduction rate (R_0) was 83.33 ± 0.331 females per female and mean generation time (T) was 14.11 ± 0.09 days. Bhatia *et al*., 2016 [2] revealed that the age-specific fecundity was 33.89 in the first day and reduced in second and third days and again increased in fourth day. The proportion of eggs laid by female at first, second, third, fourth, fifth and sixth days was 59.84, 7.16, 4.85, 15.99, 6.37 and 5.75 percent, respectively. The net reproduction rate (R_o) was 50.15 off springs per female while mean generation time (T) was 10.86 days. The intrinsic rate of increase (r_m) and finite rate of increase were 0.3701 and 1.448, respectively. Findings were also partially similar with findings of Basavaraj *et al*., 2018 [1] studied on the survival of egg, larval and pupal stages of *Helicoverpa armigera* (Hub.) on sunflower were 3, 20 and 10 days, respectively. The net reproductive rate (R_o) was 281.01offsprins per female with a mean generation length (T) was 41.40 days. The intrinsic rate of increase (r) and finite rate of increase (λ) was 0.13 females per female and 1.14 females per female per day, respectively. Kapil and Tomar, 2020 [6] reported that the intrinsic rate of increase (r) values was 0.123 at 20 °C and 0.121 at 25 °C. The rate of natural increase (r) was 0.120 at 20 °C. The highest net reproductive rate (45.86) was obtained at 20 °C. The population doubling time (DT) was maximum (10.42 days) at 15 °C and minimum (5.64 days) at 20 °C. Generation time was 47.17 days at 15°C which decreased to 24.82 days at 30 °C.

Table 1: Life and fertility table for female of *Bombyx mori* Linn. race NB_7D_2 × SH_6 at control temperature (25±1 °C).

Pivotal	**Age specific**	**Fecundity/**	**Net reproductive**		**Value of**	**% Constitution**
Age	female	Natality	Rate		$e^{-rmx}I_x.m_x$	of each group
(Day)	survivorship	rate			Where,	towards
X	*lx*	*mx*	*lx.mx*	*lxmx.X*	rm= 0.12308505	'r'
0.5-32.5 Immature stage, preoviposition period						
33.5	0.37	76.00	28.12	942.02	0.46	45.53
34.5	0.35	95.00	33.25	1147.13	0.48	47.60
35.5	0.34	88.00	29.92	1062.16	0.38	37.87
36.5	0.32	72.00	23.04	840.96	0.26	25.79
Total		331.00	114.33	3992.27	1.57	156.78

Table 2: Life and fertility table for female of *Bombyx mori* Linn. race NB_4D_2 × SH_6 at room temperature.

Pivotal	**Age specific**	**Fecundity/**	**Net reproductive**		**Value of**	**% Constitution**
Age	female	Natality	Rate		$e^{-rmx}I_x.m_x$	of each group
(Day)	survivorship	Rate			Where,	towards
X	*Lx*	*Mx*	*lx.mx*	*lxmx. X*	rm= 0.12308505	'r'
0.5-35.5 Immature stage, preoviposition period						
36.5	0.31	62.00	19.22	701.53	0.22	21.51
37.5	0.30	88.00	26.40	990.00	0.26	26.12
38.5	0.29	82.00	23.78	915.53	0.21	20.81
39.5	0.27	58.00	15.66	618.57	0.12	12.11
Total		290.00	85.06	3225.63	0.81	80.55

Table 3: Summary table of life parameters of *Bombyx mori* Linn. at control temperature (25±1 °C) and room temperature

S.N.	**Life Parameter**	**Symbol/Equation**	**Control temperature (25±1 °C)**	**Room temperature**
1.	Potential fecundity	P*f* = ∑mx	331	290
2.	Net reproductive rate	Ro = ∑lx.mx	114.33	85.06
3.	Hypothetical F_2 female	$(Ro)^2$	20831.15	7235.20
4.	Mean length of generation	T = (∑lx.mx.x)/∑lx.mx	27.66	37.92
5.	Intrinsic rate of increase 'r' Appro.	r = [$\log_e$ Ro]/T	0.07	0.05
6.	'r_m'(Accurate)	e^{-rx}lx.mx = 1	0.12308505	0.12308505
7.	Doubling Time	DT = $\log_e$ 2/r	4.3	6.02
8.	Finite rate of increase	λ = Anti $\log_e$ r_m	1.174	1.122
9.	Annual rate of increase	ARI = $Ro^{365/T}$	3.12437874527 x 10^{28}	3.75512635083×10^{18}

Conclusion

The data obtained from life and fertility table for female that the females of *Bombyx mori* Linn. race NB_4D_2 x SH_6 exhibited highest potential fecundity 331 eggs per female at control temperature (25±1 °C) and 290 eggs per female at room temperature. The net reproductive rate (R_0)114.33 was recorded at control temperature (25±1 °C) and 85.06 at room temperature. The value of intrinsic rate of increase 0.07 was recorded at control temperature (25±1 °C) and 0.05 at room temperature. The value of finite rate of increase (λ) 1.174 was recorded at control temperature (25±1 °C) and 1.122 at room temperature. The value of doubling time 4.30days was recorded at control temperature (25±1 °C) and 6.02 days at room temperature. While, the mean length of generation(T) 27.66 days at control temperature (25±1 °C) and 37.92 days at room temperature in hybrid cross NB_4D_2 x $SH_6$of mulberry silkworm.

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