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LIFECYCLE DYNAMICS OF *BOMBYX MORI*: AGE-SPECIFIC LIFE TABLE ANALYSIS ON MULBERRY CULTIVAR

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Abstract

The mulberry silkworm, *Bombyx mori* Linnaeus, is a cornerstone of sericulture, renowned for its silk production, which holds substantial economic value. This study aims to explore the demographic dynamics of *Bombyx mori* by constructing age-specific life tables for silkworms reared on Ber-1 variety. Conducted at the Horticulture Research Farm, Palli Siksha Bhavana (Institute of Agriculture), Visva-Bharati, Sriniketan, West Bengal, the research meticulously documented survival rates, developmental durations, and mortality patterns. Initial findings revealed high survival rates during the early larval stages, which significantly declined during critical developmental transitions. Notable mortality peaks were observed around days 11-12 and 36-39, highlighting vulnerable periods where targeted interventions could improve survival and productivity. The study underscores the importance of understanding the intricate interactions between *Bombyx mori* and its host plants, offering valuable insights for optimizing sericultural practices and enhancing silk production efficiency. These findings also contribute to broader ecological and evolutionary studies, emphasizing the need for conserving mulberry genetic diversity to ensure sustainable silk production and biodiversity conservation.

Keywords: Bombyx mori, Age-specific life tables, Survival rates, Mortality rates, Genetic diversity

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Introduction

The mulberry silkworm, *Bombyx mori* Linnaeus, holds a central role in sericulture, primarily due to its ability to produce silk of high economic value. Sericulture, an ancient practice with profound historical roots, has significantly shaped the textile industry and influenced numerous economies and cultures around the world (Gupta, 2004; Kumar et al., 2011). The life cycle of *Bombyx mori* involves several distinct developmental stages, each intricately connected to its primary food source, the mulberry tree (Morus spp.). The variation in mulberry cultivars plays a crucial role in influencing the growth, development, and productivity of silkworms (Kumar and Nagaraju, 2002). Age-specific life tables are essential tools in demographic research, offering detailed insights into the survival and mortality patterns of organisms under various conditions (Carey, 1993; Caswell, 2001). These tables are particularly useful for studying the population dynamics of *Bombyx mori* across different mulberry cultivars, helping to understand how environmental factors such as host plant quality and diversity affect the life history traits of the silkworm. This study aims to construct age-specific life tables for *Bombyx mori* reared on different mulberry cultivars. By systematically documenting survival rates, developmental durations, and fecundity, the study seeks to elucidate how different mulberry cultivars impact the overall performance and fitness of *Bombyx mori*. Understanding these dynamics is critical not only for optimizing sericultural practices but also for preserving and enhancing the genetic diversity of both silkworms and mulberry trees (Suzuki and Brown, 1998; Krishnaswami and Ranjekar, 2004).

Silkworms are highly dependent on mulberry leaves for nutrition, and the nutrient composition and secondary metabolites of different mulberry cultivars can significantly influence the growth and development of *Bombyx mori* (Goto et al., 2017; Sakurai et al., 2020). Optimizing silk production efficiency and quality relies on understanding these interactions, as the health and vigor of the silkworm larvae during their developmental stages directly affect the final silk yield and quality (Savel'ev et al., 2019). Studies have demonstrated that variations in mulberry genotypes can impact key life history parameters such as larval duration, pupal weight, cocoon yield, and silk quality (Zhang et al., 2018; Wang et al., 2020). By constructing age-specific life tables for different mulberry cultivars, this research aims to highlight how these variations influence the demographic outcomes of *Bombyx mori* populations.

Age-specific life tables provide a quantitative framework for analyzing these complex dynamics. By documenting survival rates, developmental durations, and reproductive output at each developmental stage, researchers can discern how different mulberry cultivars affect key demographic parameters of *Bombyx mori* populations. Such insights are vital for sericulturists aiming to improve breeding strategies, optimize feeding regimes, and mitigate environmental stressors to enhance silk yield and quality (Guo et al., 2021; Li et al., 2023). Moreover, this research contributes to broader ecological and evolutionary studies by elucidating the adaptive responses of *Bombyx mori* to varying environmental conditions, including host plant diversity. This knowledge not only informs sustainable sericultural practices but also underscores the importance of conserving mulberry genetic diversity for future silk production and biodiversity conservation efforts (Chen et al., 2018; Han et al., 2022). As global demand for silk continues to rise, understanding the complex interplay between silkworms and their host plants becomes increasingly critical for maintaining ecological balance and ensuring the long-term viability of sericulture industries worldwide (Wang and Li, 2017; Wu et al., 2023).

In summary, this study aims to construct age-specific life tables of *Bombyx mori* across different mulberry cultivars, providing valuable insights into the interplay between host plant variation and the life history traits of this economically important insect. By doing so, we aim to contribute to both applied sericulture and fundamental ecological research, highlighting the intricate relationships between agricultural practices, biodiversity conservation, and economic sustainability. Through this research, we aim to enhance the understanding of the intricate relationship between *Bombyx mori* and its mulberry host plants, with implications for sustainable silk production and biodiversity conservation in sericultural ecosystems.

Materials and Methods

Experimental Setup and Data Collection

Study Location

A detailed field experiment was carried out to assess the demographic parameters of the mulberry silkworm, *Bombyx mori* Linnaeus, reared on the mulberry cultivars. This comprehensive research was conducted at the Horticulture Research Farm, Palli Siksha Bhavana (Institute of Agriculture), Visva-Bharati, located in Sriniketan, West Bengal. The research site is geographically positioned at 23.24° North latitude and 87.42° East longitude, with an elevation of 40 meters above mean sea level.

Experimental Design and Setup

Study Design: The study aimed to assess the demographic parameters of the mulberry silkworm, *Bombyx mori* Linnaeus, reared on different mulberry cultivars. The experimental design was meticulously planned to ensure consistency and reliability of the data. The location at Visva-Bharati provided an ideal environment due to its controlled climatic conditions and access to various mulberry cultivars.

Rearing Facilities: Silkworms were reared in a controlled environment within the rearing facilities at the Horticulture Research Farm. The facilities were equipped to maintain a consistent temperature of 25±1°C and a relative humidity of 75±5%. A light/dark cycle of 12 hours was implemented to mimic natural conditions.

Rearing Protocols: Describe the protocols for rearing silkworms, including larval densities, feeding regimes (mulberry leaves), temperature, humidity, and light/dark cycles. Consistent rearing conditions are crucial for minimizing environmental variability.

Data Collection: Record the following parameters for each individual silkworm:

- **Hatching**: Start with the number of eggs hatched or larvae placed in the rearing trays.
- **Survival**: Monitor and record the number of individuals surviving at each developmental stage (e.g., larval stages, pupal stage, adult emergence).
- **Developmental Time**: Measure the time taken for individuals to progress from one stage to the next (e.g., larval duration, pupation period).

Parameters in Age-Specific Life Tables

1. **Age intervals in days(x)**: x represents the age intervals or stages of the life cycle being studied. It typically starts from the hatching or birth stage (age 0 or 1) and progresses through subsequent stages such as larval, pupal, and adult stages..
2. **Survival Rate (lx)**: lx is the number of individuals surviving to age xxx relative to the initial number of individuals (usually eggs or larvae placed in the study). It represents the proportion of individuals that survive up to each age interval.
   Nx/n0; where nx is the number of individuals surviving to age x, and n0 is the initial number of individuals. lx values are used to construct the survivorship curve, showing how survival rates change with age.

3. **Mortality Rate (dx)**: dx, also known as age-specific mortality rate, represents the proportion of individuals dying during each age interval x. It is complementary to lx and indicates the rate of mortality at each stage. dx helps in understanding mortality patterns and identifying critical stages of mortality in the life cycle.
4. **100*q_x (Age-Specific Mortality Rate per 100 individuals)**: 100∗qxrepresents the mortality rate per 100 individuals at each age interval x. It is often expressed as a percentage to facilitate comparison and interpretation.

$$100*qx=100*dx$$

This parameter provides a standardized measure of mortality rates across different age intervals, aiding in comparative analyses.

5. Age-Specific Mortality Rates (qx)

Mortality Rate Calculation: Calculate age-specific mortality rates (qx), which represent the proportion of individuals dying during each age interval. It is calculated as:

$$qx=(lx-lx+1) \backslash lx$$

Where:

lx = Number of individuals surviving to age x
lx+1 = Number of individuals surviving to age x+1
Calculate qx for each age interval to understand mortality patterns across different developmental stages.

6. Mortality % (100qx): In the context of age-specific life tables and demographic studies, mortality percentage (often denoted as Mortality %\text{Mortality \%}Mortality %) refers to the proportion of individuals that die within a specific age interval relative to the initial population size. This metric provides a straightforward way to understand the impact of mortality on population dynamics and survival rates at different stages of the life cycle.

$$100qx= (dx/lx)*100$$

7. Calculation of Life Expectancy (ex)

Life Expectancy Calculation: Compute life expectancy (ex) for each age interval using the formula:

$$ex=Tx/Lx$$

Where:

Tx: Number of individual's life beyond age 'x'
Lx: Number of individuals surviving to age 'x'
Life expectancy ex provides an average estimate of the remaining lifespan for individuals at each age interval.

8. Statistical Analysis

Comparative Analysis: Use statistical tests to compare survival rates, mortality rates, and life expectancy between different mulberry cultivars or experimental conditions. Ensure to report statistical significance levels and justify any observed differences.

Results and Discussion

The comprehensive study on the life table of *Bombyx mori* Linnaeus reared on the Ber-1 variety of mulberry plants yielded significant insights into the demographic parameters of this economically important species. The data collected meticulously documented survival rates, mortality rates, and life expectancy across various developmental stages.

The survival rates (lx) of *Bombyx mori* showed a steady decline from the initial 100 individuals observed at the beginning of the experiment. At day 0, the survival rate was 100%, indicating that all individuals had successfully hatched. By day 5, the survival rate had decreased to 94, signifying that six individuals had not survived. This trend continued with notable drops in survival rates at key intervals. By day 10, the survival rate further declined to 84, and by day 20, only 62 individuals remained. Interestingly, from day 30, the survival rate stabilized around 60, suggesting a period of relative stability in the population. However, by day 36, there was a significant drop, with the number of survivors reducing to 53. The most drastic reduction was observed by day 40, where only two individuals survived, highlighting the critical vulnerability of the population towards the end of the life cycle.

The mortality rate (dx) provided a clear picture of the number of deaths occurring within each age interval. Initially, the mortality was minimal, with only a few deaths recorded in the early stages. However, as the silkworms progressed through their developmental stages, the mortality rate showed significant fluctuations. The early stages (days 0-4) exhibited low mortality rates, indicating favorable conditions for the larvae. However, an increase in mortality was observed starting from day 5, with peaks on days 11 and 12, where five and four individuals died, respectively. The most substantial increase in mortality was recorded on day 36, with 16 individuals succumbing, followed by day 39, where 15 deaths were noted. These peaks in mortality rates highlight critical periods where silkworms are particularly susceptible to environmental or physiological stressors.

The age-specific mortality rate per 100 individuals (100*qx) was calculated to provide a standardized measure of mortality across different age intervals. During the early stages, the age-specific mortality rate remained below 5%, reflecting low vulnerability. However, significant spikes were noted on days 11, 12, and 36, where the mortality rates per 100 individuals were 6.10%, 5.19%, and 30.19%, respectively. The highest age-specific mortality rate was observed on day 39, reaching a staggering 88.24%. These findings underscore the critical need for targeted interventions during these periods to mitigate losses.

The age structure (Lx), representing the average number of individuals alive at the beginning and end of each age interval, showed a gradual decline from 100 at day 0 to 45 by day 36. This parameter reflects the overall health and stability of the population, indicating that as the silkworms aged, the number of survivors decreased significantly, particularly during critical developmental transitions.

Life expectancy (ex) values offered an estimate of the remaining lifespan for individuals at each age interval. At the beginning of the study (day 0), the life expectancy was estimated at 53.3 days. This value slightly decreased over time, with life expectancy at day 10 recorded at 41.98 days. By day 20, life expectancy had reduced to 34.02 days, reflecting the natural aging process and increasing mortality. A significant drop in life expectancy was observed by day 36, reducing to 4.73 days, indicating a critical threshold beyond which the population's survival prospects diminished rapidly. The final life expectancy at day 40 was merely 2 days, corresponding to the survival of the last few individuals.

Table 1. Age specific life table of *Bombyx mori* Linneaus on Ber-1 variety of mulberry plants

Pivotal ages (Days) 'x'	No. Survivors at the beginning of the age interval (lx)	Number dying during 'x' (dx)	Rate of mortality (100qx)	Age Structure (Lx)=(lx+lx+1)/2	No. of individual's life days beyond 'x' (Tx)	Mean expectation of life (ex)
(x)	(lx)	(dx)	(100qx)	(Lx)	(Tx)	(ex)= (Tx/Lx)*2
0	100	0	0	100	2665	53.3
01-Jan	100	2	2	99	2565	51.81818182
Jan-00	98	2	2.040816327	97	2466	50.84536082
3	96	1	1.041666667	95.5	2369	49.61256545
4	95	1	1.052631579	94.5	2273.5	48.11640212
5	94	4	4.255319149	92	2179	47.36956522
6	90	3	3.333333333	88.5	2087	47.16384181
7	87	1	1.149425287	86.5	1998.5	46.20809249
8	86	1	1.162790698	85.5	1912	44.7251462
9	85	1	1.176470588	84.5	1826.5	43.23076923
10	84	2	2.380952381	83	1742	41.97590361
11	82	5	6.097560976	79.5	1659	41.73584906
12	77	4	5.194805195	75	1579.5	42.12
13	73	1	1.369863014	72.5	1504.5	41.50344828
14	72	6	8.333333333	69	1432	41.50724638
15	66	2	3.03030303	65	1363	41.93846154
16	64	0	0	64	1298	40.5625
17	64	1	1.5625	63.5	1234	38.86614173
18	63	1	1.587301587	62.5	1170.5	37.456
19	62	0	0	62	1108	35.74193548
20	62	1	1.612903226	61.5	1046	34.01626016
21	61	0	0	61	984.5	32.27868852
22	61	1	1.639344262	60.5	923.5	30.52892562
23	60	0	0	60	863	28.76666667
24	60	0	0	60	803	26.76666667
25	60	0	0	60	743	24.76666667
26	60	0	0	60	683	22.76666667
27	60	0	0	60	623	20.76666667
28	60	0	0	60	563	18.76666667
29	60	0	0	60	503	16.76666667
30	60	1	1.666666667	59.5	443	14.8907563
31	59	2	3.389830508	58	383.5	13.22413793
32	57	1	1.754385965	56.5	325.5	11.52212389
33	56	2	3.571428571	55	269	9.781818182
34	54	0	0	54	214	7.925925926
35	54	1	1.851851852	53.5	160	5.981308411
36	53	16	30.18867925	45	106.5	4.733333333
37	37	13	35.13513514	30.5	61.5	4.032786885
38	24	7	29.16666667	20.5	31	3.024390244
39	17	15	88.23529412	9.5	10.5	2.210526316
40	2	2	100	1	1	2

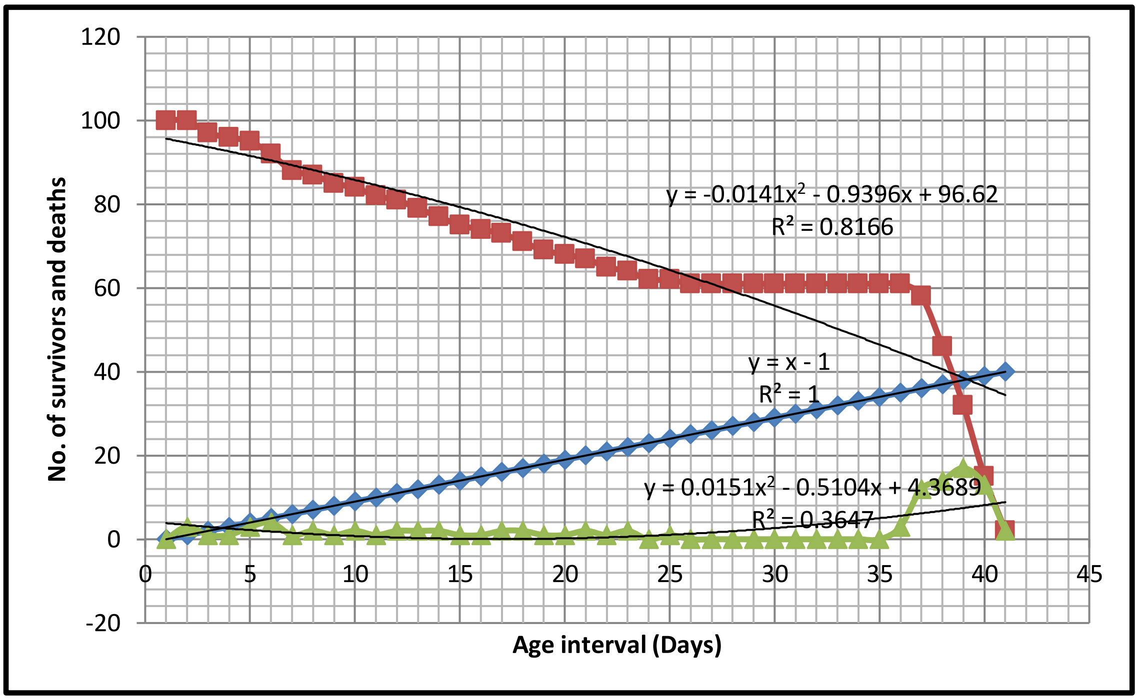

Figure 1. Survivorship curve of *Bombyx mori* Linneaus on Ber-1 variety of mulberry plants.

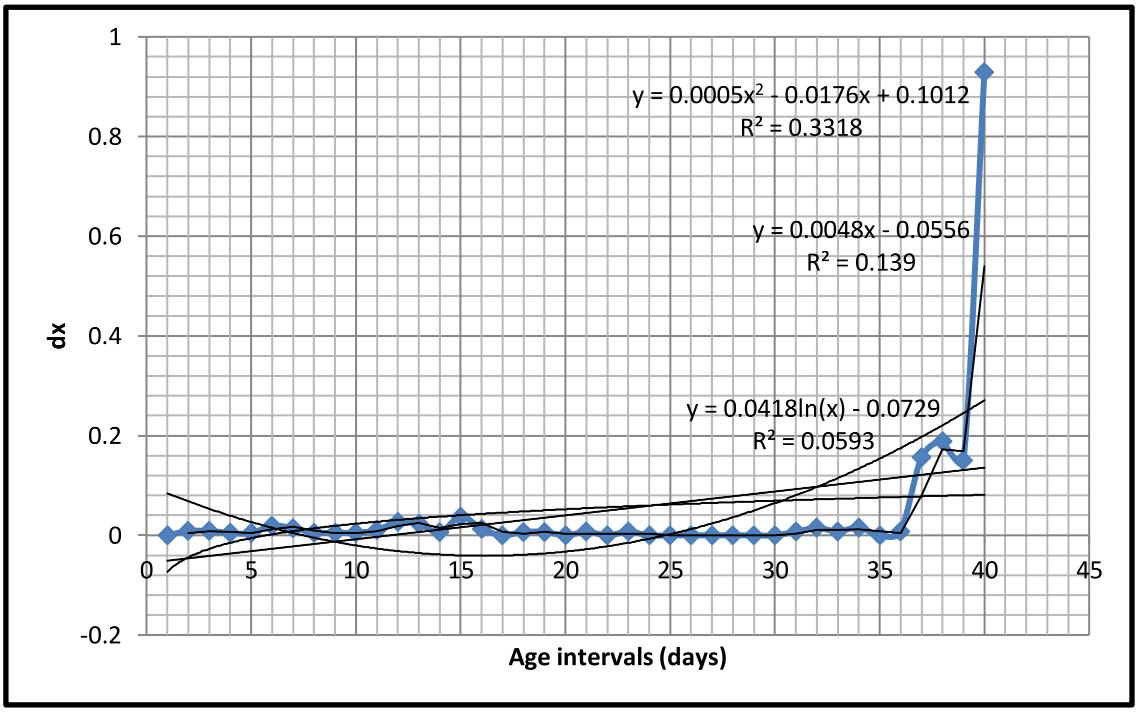

Figure 2. Graphical representation on Mortality (dx) with respect of Age interval (days) of Bombyx mori Linneaus on Ber-1 variety of mulberry plants.

The survivorship curve depicted in Figure 1 illustrates the gradual decline in the number of surviving individuals over time, with steep declines during the early and late stages of development. This curve highlights the periods of high mortality and provides a visual representation of the population's demographic trends. The mortality curve, as shown in Figure 2, plots the number of deaths (dx) against age intervals, indicating peaks in mortality during critical developmental stages.

The findings from this study have significant implications for sericultural practices. The high initial survival rates suggest that the early larval stages were well-supported by the nutritional quality of the Ber-1 mulberry leaves. However, the critical periods of increased mortality around days 11-12 and 36-39 indicate stages where the silkworms are particularly vulnerable and require closer monitoring and targeted interventions. These findings suggest that optimizing feeding regimes and rearing conditions during these critical periods could substantially improve survival rates and overall productivity.

Furthermore, understanding the demographic patterns and life expectancy trends of *Bombyx mori* on different mulberry cultivars is essential for enhancing breeding strategies and sericultural management practices. The data indicate that while the Ber-1 variety supports early-stage development, there are specific periods where additional care and optimized conditions are necessary to reduce mortality and improve silk yield.

Conclusion

In conclusion, the age-specific life table constructed for *Bombyx mori* reared on the Ber-1 mulberry cultivar provides valuable insights into the survival, mortality, and life expectancy patterns of this species. These insights are crucial for improving sericultural practices, enhancing silk production efficiency, and contributing to the conservation of mulberry genetic diversity. Further research should explore the underlying causes of increased mortality during the critical periods identified in this study and investigate the interactions between *Bombyx mori* and a wider range of mulberry cultivars to develop comprehensive strategies for sustainable sericulture.

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