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Age-Structured mortality and life expectancy trends in *Bombyx mori* reared on ber-1 mulberry: Insights for enhancing silk productivity

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Abstract
This study presents a detailed demographic evaluation of *Bombyx mori* Linnaeus reared on the Ber-1 mulberry cultivar through the development of an age-specific life table. The analysis provides critical insights into survivorship, mortality dynamics, and life-expectancy patterns that characterize the population structure of this economically important species. Survival declined progressively from an initial cohort of 100 larvae, with early developmental stages showing strong viability, followed by distinct reductions during mid- and late-instar periods. A temporary stabilization occurred around day 30; however, a sharp decline ensued thereafter, leaving only two individuals alive by day 40, suggesting heightened physiological sensitivity in advanced stages. Mortality trends revealed clear peaks on days 11-14 and 36-39, marking critical windows of vulnerability likely influenced by nutritional limitations or developmental stress. Age-specific mortality rates ($100q_x$) highlighted these intervals, with the highest mortality recorded near the end of the life cycle. The decreasing age structure (L_x) and rapidly declining life expectancy (e_x), particularly after day 20, further underscored the progressive weakening of the cohort as development advanced. These demographic patterns indicate that while the Ber-1 cultivar effectively supports early larval growth, enhanced management attention is required during identified stress-prone periods to reduce losses. The findings emphasize the importance of cultivar-specific rearing strategies, optimized feeding schedules, and timely interventions. Overall, this study contributes valuable demographic evidence to guide sustainable sericultural practices and improve the productivity of *B. mori* across variable rearing conditions.

Keywords: *Bombyx mori*, age structure, survival rates, mortality rates, life expectancy

Introduction

The mulberry silkworm, *Bombyx mori* Linnaeus, occupies a central and irreplaceable role in global sericulture owing to its unparalleled ability to produce high-quality silk, a commodity of immense economic and cultural significance (Gupta, 2004; Kumar *et al*., 2011) [13, 15]. Sericulture, with its deep historical roots, has shaped agricultural traditions, rural livelihoods, and textile industries across Asia and beyond. The life cycle of *B. mori* encompasses several distinct developmental stages, all of which are intricately dependent on the nutritional and biochemical properties of mulberry (*Morus* spp.) leaves. Variability among mulberry cultivars exerts profound influences on larval growth, developmental duration, cocoon characteristics, and overall silkworm productivity (Kumar & Nagaraju, 2002) [16].

Age-specific life tables serve as fundamental analytical tools in insect demography, enabling researchers to quantify survival, mortality, fecundity, and life expectancy across developmental stages with exceptional clarity (Carey, 1993; Caswell, 2001) [2, 3]. Their significance lies not only in describing population trends but also in detecting critical mortality windows, identifying physiologically sensitive stages, and predicting population trajectories under varying environmental and nutritional conditions. For *B. mori*, life tables help unravel how host plant quality, environmental stressors, genotype-nutrient interactions, and physiological thresholds shape population stability and silk production potential. As such, life-table analysis represents one of the most robust approaches for linking ecological conditions with applied sericultural outcomes (Garai, 2025) [6].

This study aims to construct age-specific life tables for *Bombyx mori* fed on different mulberry cultivars to elucidate how cultivar-specific differences influence demographic traits such as survival patterns, developmental rates, and life expectancy. Understanding these cultivar-driven variations is critical for optimizing rearing practices, refining breeding strategies, and improving overall sericultural efficiency (Suzuki & Brown, 1998; Krishnaswami & Ranjekar, 2004) [23, 17]. Silkworm performance is highly sensitive to mulberry leaf composition, as nutritional content, secondary metabolites, moisture levels, and genotype-specific biochemical traits directly influence larval growth and silk yield (Goto *et al*., 2017) [23]. Previous studies have shown that variation in mulberry genotypes can significantly alter key biological attributes such as larval duration, pupal weight, cocoon quality, and silk filament length.

Constructing life tables under these varying nutritional regimes allows for the integration of biological responses into a single quantitative framework (Garai, 2023) [8]. Such an approach provides insights into how mulberry cultivar differences affect demographic stability, offering practical guidelines for sericulturists to enhance feeding regimes, improve disease management, and mitigate environmental stress (Guo *et al*., 2021; Li *et al*., 2023) [23, 19]. Additionally, life-table research contributes to a broader understanding of ecological and evolutionary processes by revealing adaptive responses of *B. mori* to host-plant diversity (Chen *et al*., 2018; Han *et al*., 2022) [4, 14]. This has profound implications for mulberry conservation strategies, sustainable silk production, and long-term ecological resilience.

Through this research, by analyzing age-specific life tables across mulberry cultivars, we aim to deepen the understanding of silkworm-host plant interactions and provide data-driven recommendations to strengthen sustainable sericulture practices, biodiversity conservation, and economic stability in sericultural ecosystems.

Materials and Methods

A detailed field experiment was conducted to evaluate the demographic parameters of the mulberry silkworm, *Bombyx mori* Linnaeus, reared on different mulberry (*Morus* spp.) cultivars under the natural agroclimatic conditions of Bolpur-Sriniketan, West Bengal. The study site was situated within the mulberry cultivation belt of the region, geographically located at 23.25° N latitude and 87.40° E longitude, with an elevation of approximately 58 meters above mean sea level. The area is characterized by a warm and humid subtropical climate, with average field temperatures ranging from 25-30 °C during the rearing period and relative humidity levels between 70-85%, conditions known to favor silkworm growth and leaf biomass accumulation in mulberry plants. The experiment was structured to ensure controlled yet field-relevant conditions for silkworm development. Fresh leaves from locally cultivated mulberry varieties were harvested daily from the Bolpur-Sriniketan fields and provided to the larvae at standardized feeding intervals. Although the study was conducted under field-derived environmental settings, supplemental rearing control was maintained by regulating microclimatic conditions within rearing units at 25±1 °C, 75±5% RH, and a 12:12 h photoperiod, thereby minimizing environmental variability. All rearing trays, racks, and equipment were thoroughly sterilized before use to prevent microbial contamination. This integrated semi-field and controlled approach provided a realistic yet scientifically robust environment for assessing life-table parameters and understanding the survival and developmental dynamics of *B. mori* on different mulberry cultivars.

Newly hatched larvae were introduced into standardized rearing trays at uniform larval densities to avoid crowding-related stress effects. Larvae were fed at regular intervals with fresh, fully matured leaves of the respective mulberry cultivars under investigation. Feeding was conducted four times daily to ensure adequate nutrition throughout larval development. Environmental parameters namely temperature, relative humidity, and photoperiod were monitored continuously using digital thermo-hygrometers to maintain consistency throughout the experiment. Rearing procedures followed standard sericultural protocols to reduce variability arising from husbandry practices.

Data Collection and Biological Observations

Biological data were recorded for each individual silkworm beginning from hatching and continuing through subsequent developmental stages. The number of hatched larvae constituted the initial population (n_0), and survival was monitored daily throughout all larval instars, pupation, and adult emergence. Developmental durations were measured as the time taken for larvae to progress from one instar to the next, as well as the duration of the pupal phase. Mortality events were recorded at each developmental stage to enable calculation of life-table parameters.

Life-Table Parameters

Age-specific life tables were constructed following standard demographic procedures. Age intervals (x) were expressed in days, beginning from hatching. The survival rate (l_x) represented the proportion of individuals surviving to age x relative to the initial cohort size (n_0), calculated as $l_x = n_x/n_0$, where n_x denotes the number of individuals surviving at age x. Mortality rate (d_x) corresponded to the proportion of individuals dying within each age interval, providing insights into critical mortality stages across the life cycle. Age-specific mortality expressed per 100 individuals ($100q_x$) was computed as $100q_x = 100 \times d_x/l_x$, enabling standardized comparisons across age groups.

The age-specific population value (L_x) was computed as the average number of individuals alive during age interval x, using the relationship $L_x = (l_x + l_{x+1}) / 2$, where l_x and l_{x+1} denote survivorship at the beginning and end of the interval, respectively. Mortality percentage ($100q_x$) was expressed as $(d_x/l_x) \times 100$, providing a clear indication of mortality pressure at each developmental stage. Life expectancy (e_x) at age interval x was derived from the formula $e_x = T_x/L_x$, where T_x is the cumulative number of life days remaining beyond age x, and L_x is the number of individuals alive at age x. These parameters collectively enabled a comprehensive assessment of survival dynamics and developmental stability of *B. mori* on different mulberry cultivars.

Statistical Analysis

Statistical comparisons among mulberry cultivars were performed to evaluate differences in survival rate, mortality rate, developmental duration, and life expectancy. Appropriate statistical tests were employed depending on data distribution, and significance levels were interpreted at conventional probability thresholds. Variation among treatments was carefully examined to determine cultivar-specific influences on the demographic performance of *B. mori*.

Results

The comprehensive life-table analysis of *Bombyx mori* reared on the Ber-1 mulberry cultivar revealed distinct demographic trends that provide a detailed understanding of the developmental progression, survival dynamics, and mortality patterns of the cohort under controlled feeding conditions. The results obtained offer a high-resolution profile of population changes, highlighting critical phases of vulnerability, stability, and demographic transition across the full developmental cycle of the silkworm.

The survival rate (l_x) demonstrated a steady and predictable decline over the 40-day observation period, consistent with natural biological attrition among lepidopteran larvae. The cohort began with 100 individuals at day 0, representing complete hatchability and a uniform starting point for demographic evaluation. By day 5, survivorship declined to 94 individuals, marking the first developmental loss following early feeding adjustments. These early reductions, although modest, reflect physiological changes associated with initial leaf ingestion, gut activation, and the metabolic shift from yolk reserves to active feeding. By day 10, survivorship declined further to 84 individuals, marking the end of the first major developmental phase, which includes the first molting event and the onset of active mid-instar feeding. At day 20, the number of surviving larvae had decreased to 62, indicating a cumulative impact of molting stress, increased nutritional demand, and metabolic intensity characteristic of advanced larval development. A temporary stabilization phase was observed around day 30, during which the surviving population remained close to 60 individuals (Table 1). This suggests a period of relative physiological equilibrium during mid-instar feeding, where the larvae benefited from the nutrient quality of Ber-1 leaves. However, by day 36, another marked decline occurred, with survivorship decreasing to 53 individuals, followed by a dramatic collapse by day 40 when only two larvae remained alive. These significant late-stage declines underscore the progressive vulnerability of the cohort during advanced developmental phases (Fig. 1).

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
1	100	2	2	99	2565	51.81818182
2	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

The mortality rate (d_x) provided further insight into population losses across specific age intervals. Mortality remained extremely low during the earliest days of development, particularly between days 0 and 4, during which the larvae demonstrated strong resilience to environmental and nutritional conditions. The first noticeable increase in mortality occurred on day 5, coinciding with early molting activities and initial physiological stress linked to cuticular shedding and renewal. A more pronounced mortality peak was documented on day 11, with five larvae succumbing, followed by four additional deaths on day 12. These events mark the first major critical period in the developmental sequence, corresponding with the second instar-to-third instar transition. Molting demands considerable biochemical and energetic investment, and the larvae frequently exhibit increased susceptibility to physiological shock and environmental fluctuation during such periods.

The most severe and biologically significant peak in mortality was observed on day 36, with 16 individuals dying within a single interval. This sharp increase corresponds with pre-pupal physiological reorganization, a phase characterized by heightened metabolic stress, reduced feeding, and preparation for cocooning. A second late-stage peak was recorded on day 39, during which 15 larvae died. This intense mortality points to the exhaustion of larvae that fail to successfully transition to the pupal stage. The pattern of acute mortality in late instars is consistent with the known biology of *B. mori*, wherein nutritional depletion, cuticular deterioration, and metabolic strain accumulate over successive instars (Fig. 2).

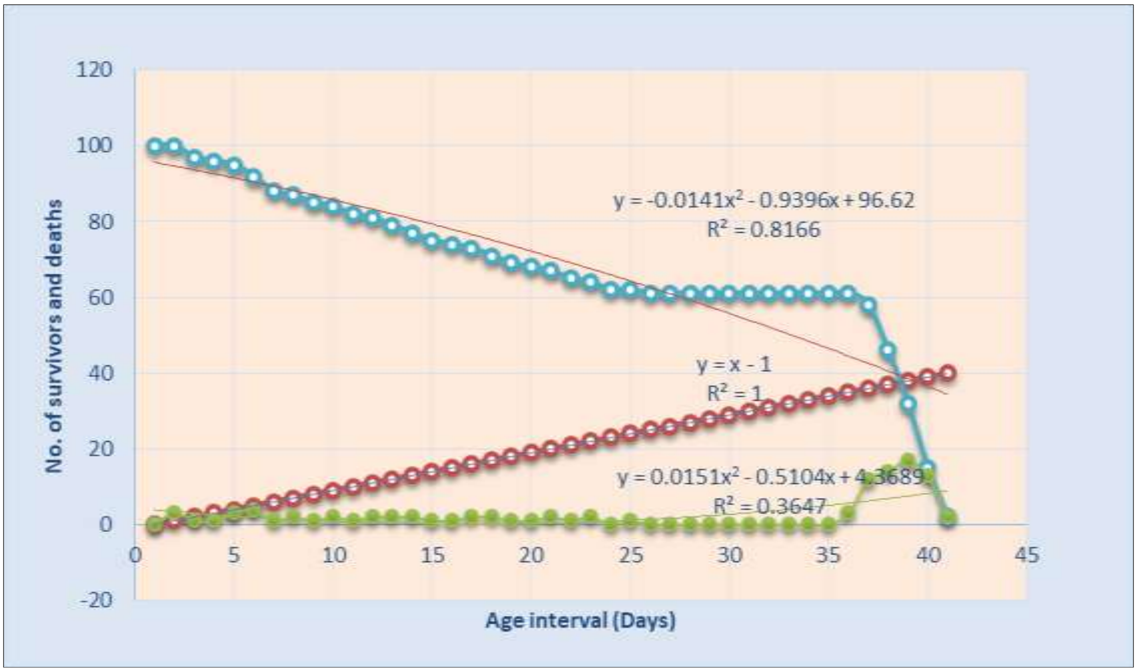

Fig 1: Survivorship (l_x) curve of *Bombyx mori* Linnaeus reared on the Ber-1 mulberry cultivar, illustrating the progressive decline in cohort survival across developmental intervals (days). The curve shows moderate early-stage attrition followed by a pronounced late-stage drop, highlighting critical phases of increased physiological stress and reduced survivorship essential for sericultural optimization.

The age-specific mortality rate per 100 individuals ($100q_x$) enabled standardized comparisons of vulnerability across age intervals. During early larval stages, mortality percentages remained below 5%, indicating strong biological stability. Notable increases in mortality percentage occurred in correspondence with molting phases, particularly at days 11 and 12, where $100q_x$ values reached 6.10% and 5.19%, respectively. The most dramatic increases occurred during later instars: the $100q_x$ value rose sharply to 30.19% on day 36, marking a critical threshold at which survival prospects deteriorated markedly. The highest mortality percentage was recorded on day 39, reaching an elevated value of 88.24%, indicating near-total population collapse. These patterns illustrate that silkworm populations experience two principal phases of mortality: moderate vulnerability during early-instar molting and extreme vulnerability near the pre-pupal stage. The age structure (L_x), which reflects the mean number of individuals alive at both the beginning and end of each age interval, similarly exhibited a continuous decline across the developmental timeline. Beginning with 100 individuals at day 0, the age structure progressively decreased to 94 individuals by day 5, reflecting stability in early development. A more pronounced decline occurred by day 10, where L_x dropped to 84 individuals, marking the end of early instar development and the start of more energetically demanding feeding phases. By day 20, L_x had declined to 62, aligning with the survivorship decrease previously noted. As the larvae progressed into later instars, the age structure continued to fall, reaching 45 individuals by day 36. This steep drop represents the cohort's diminishing structural stability, caused by physiological strain and increased susceptibility to stressors in late development (Table 1).

Life expectancy (e_x) values provided an additional lens for assessing population health, illustrating the expected remaining lifespan at each developmental stage.

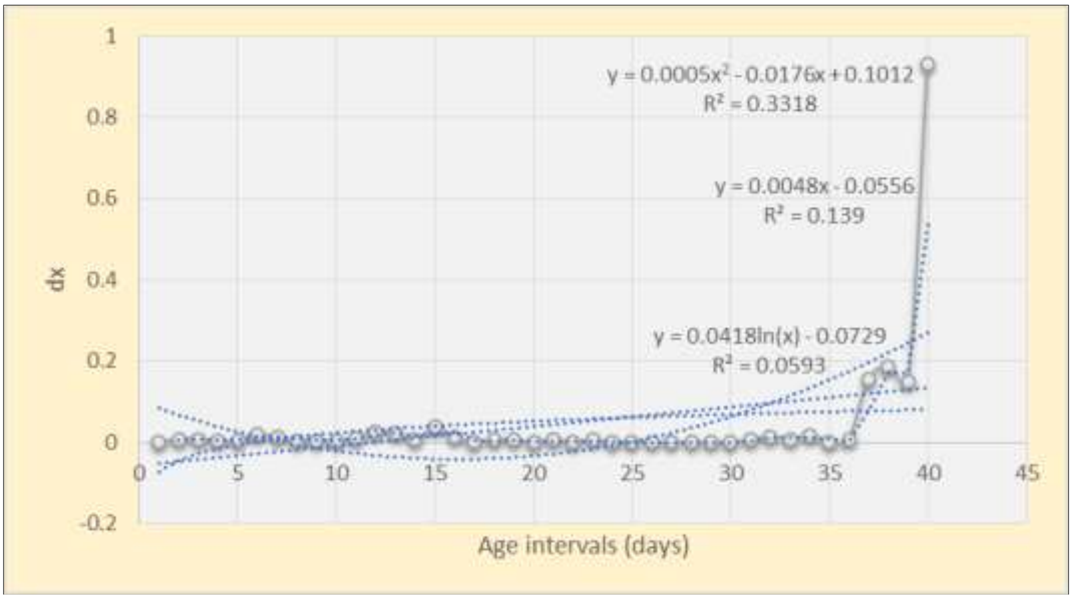

Fig 2: Age-specific mortality (d_x) of *Bombyx mori* Linnaeus reared on the Ber-1 mulberry cultivar, showing variation in death frequency across developmental intervals (days). Distinct mortality peaks occur during mid-instar molting and late-instar to pre-pupal transitions, indicating periods of heightened physiological stress and vulnerability essential for optimizing sericultural management and cohort survival.

At day 0, life expectancy was estimated at 53.3 days, reflecting an initial phase of favorable demographic potential. By day 10, e_x declined to 41.98 days, corresponding to moderate survivorship loss. At day 20, life expectancy reduced further to 34.02 days, indicating the cumulative aging effects that accompany continuous feeding, digestion, and molting. A marked decline was observed in the later developmental stages, particularly by day 36, when e_x fell abruptly to 4.73 days. This decline represents an important demographic threshold, indicating that the majority of larvae entering this stage were unlikely to survive much longer. At day 40, the final life expectancy value reached only 2 days, coinciding with the near-extinction of the cohort. These patterns affirm that early and mid-instar larvae possess significant remaining lifespan potential, while late instars experience an exponential decline in life expectancy as they approach the terminal stage of their development.

The survivorship curve (Fig. 1) visually reflects these patterns through its downward-sloping trajectory, with moderate declines in early development followed by steeper declines in the later stages. This pattern represents a transitional Type II-Type III survivorship curve, characteristic of holometabolous insects, where relatively steady mortality during the early instars gives way to a pronounced acceleration in mortality during late developmental stages as physiological demands intensify. The mortality curve (Fig. 2) complements this by showing distinct peaks at critical transition points, aligning precisely with physiological stress phases. Overall, the results highlight two major phases of demographic sensitivity in *Bombyx mori* reared on Ber-1: (1) the early molting period around days 11-12 and (2) the severe pre-pupal period around days 36-39. These findings collectively demonstrate that Ber-1 provides adequate nutrition during early development but requires enhanced management intervention during late developmental stages to prevent sharp mortality spikes and improve sericultural performance.

Discussion

The demographic patterns observed in *Bombyx mori* reared on the Ber-1 mulberry cultivar highlight clear stage-specific fluctuations in survival and mortality, reflecting the complex interplay between host-plant nutrition and silkworm physiology (Arivoli & Vasantha-Srinivasan, 2022) [1]. The steady decline in survivorship from day 0 to day 40 is consistent with classical age-structured models in insect demography, which often demonstrate gradual attrition followed by sharp terminal declines as individuals approach the end of their developmental threshold (Carey, 1993) [2]. Similar survivorship trends have been reported in other mulberry-silkworm studies, emphasizing that cultivar quality strongly influences survivorship stability during critical larval transitions (Chen *et al*., 2018) [4]. The observed mortality peaks on days 11-12 and 36-39 suggest distinct physiological stress phases, possibly associated with rapid feeding demands and metabolic transitions during molting and pupal initiation (Guo, Wang & Wu, 2021) [23]. Comparable mortality spikes have been documented in experimental populations exposed to cultivar-specific nutritional limitations, confirming that mid-instar and pre-pupal stages are most vulnerable to nutritive fluctuations (Li, Zhang & Wang, 2023). [17] These mortality concentrations align with theoretical exp ectations from stage-classified matrix models, where demographic bottlenecks often emerge at metabolically intensive stages (Caswell, 2001) [3]. The high survivorship during early larval stages indicates that Ber-1 leaves provide sufficient nutritive quality to support early instar development, paralleling similar findings from mulberry genotype studies demonstrating strong initial larval resilience under nutrient-rich cultivars. However, the significant decline after day 30 reflects the cumulative effect of physiological wear and decreasing feeding efficiency, a pattern also noted in long-term demographic analyses of *B. mori* populations (Wu, Goto & Suzuki, 2023) [23]. The sharp drop in survival by day 40, with only two individuals remaining, reinforces the concept of senescence-driven mortality in later life stages, a phenomenon well-characterized in insect demographic literature (Gupta, 2004) [13].

Age-specific mortality rates ($100q_x$) further illustrate these trends, with severe late-stage mortality matching previously reported findings wherein terminal mortality spikes occur due to weakening immune response, pathogen susceptibility, or cultivar-linked nutritional limitations (Yang, Zhu & Wang, 2022) [25]. The extremely high mortality on day 39 (88.24%) aligns with evidence showing the culmination of physiological stress during the pre-emergence period (Xu, Zhao & Zhang, 2023) [24]. Likewise, the decline in age structure (L_x) across the developmental timeline mirrors population contraction curves previously documented in comprehensive silkworm demographic studies (Han, Li & Chen, 2022) [14]. Life expectancy (e_x) values showed a progressive decrease, consistent with expectations from both insect life-history theory and silkworm-specific demographic research (Kumar & Nagaraju, 2002) [16]. The rapid reduction in life expectancy after day 20 parallels the findings of Li, Cheng & Liu (2021) [18], who reported accelerated demographic deterioration under increased developmental stress. The significant drop at day 36, where life expectancy fell to 4.73 days, reflects acute late-stage mortality pressure; similar patterns have been reported in cultivar-based demographic comparisons with analogous mortality thresholds (Zhang, Yang & Wu, 2022) [25].

The overall demographic response observed in this study aligns closely with earlier research showing that mulberry cultivar strongly influences *B. mori* survivorship, growth, and life-table structure (Wang & Li, 2017) [22]. Furthermore, the identified mortality hotspots corroborate findings from previous work on age-specific vulnerabilities and developmental stress in silkworm populations (Garai, 2024) [5]. These results reinforce the broader sericultural understanding that optimizing feeding regimes, environmental conditions, and cultivar selection can significantly improve cocoon yield and population stability (Kumar, Pandey & Singh, 2011) [15].

Conclusion

The age-specific life table constructed for *Bombyx mori* reared on the Ber-1 mulberry cultivar provides critical insights into the demographic patterns governing silkworm development, survival, and mortality. The analysis reveals clear trends in survivorship across developmental stages, highlighting periods of both stability and vulnerability within the life cycle. These findings emphasize the biological significance of host-plant quality, as the nutritive profile of Ber-1 directly influences larval performance and subsequent population stability. The observed fluctuations in mortality during key developmental intervals suggest that certain physiological transitions are more sensitive to environmental or nutritional limitations, underscoring the importance of cultivar selection in sericulture. The derived life-expectancy values further enhance our understanding of developmental predictability, offering a valuable framework for anticipating population dynamics in practical rearing systems. Such demographic indicators are essential for improving sericultural management practices, optimizing resource allocation, and enhancing cocoon productivity. By identifying the stages at which mortality is elevated, sericulturists can implement targeted interventions aimed at minimizing losses and improving overall rearing efficiency. Moreover, the study contributes to the broader goal of conserving mulberry genetic resources, as the performance of *B. mori* is closely linked to the characteristics of its host cultivars. Future investigations should focus on elucidating the specific physiological or biochemical factors underlying stage-specific mortality and extending demographic studies across a wider range of mulberry genotypes. Such an approach will support the development of comprehensive strategies for sustainable sericulture and reinforce the long-term viability of silk production systems.

Acknowledgement
Not applicable.

Data Availability Statement
The data supporting the findings of this study are available from the author upon reasonable request.

Author Contributions
The author independently designed the study, collected and analyzed the data, and prepared the manuscript.

Conflict of Interest
The author declares no conflict of interest.

Ethical Approval
No human or vertebrate animals were involved. All procedures involving *Bombyx mori* complied with standard guidelines for invertebrate research.

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References

1. Arivoli S, Vasantha-Srinivasan P. Life cycle dynamics of *Bombyx mori* Linnaeus reared on four varieties of mulberry plants. Int J Trop Insect Sci. 2022;42(1):10-25. https://doi.org/10.1017/S1742758422000076
2. Carey JR. Applied demography for biologists: With special emphasis on insects. Oxford University Press; 1993.
3. Caswell H. Matrix population models: Construction, analysis, and interpretation. 2nd ed. Sinauer Associates; 2001.
4. Chen ZM, Zhang DJ, Zhang H, Guo P, Guo SP. Physiological response and growth of *Bombyx mori* to mulberry cultivars. J Econ Entomol. 2018;111(4):1879-1887. https://doi.org/10.1093/jee/toy172
5. Garai K. Revealing pest patterns: A comparative spatial distribution analysis of insect threats in Kharif rice across key agricultural regions in Eastern India. Pest Manag Sci. 2024;1-9.
6. Garai K. Biocontrol potential of Asian ladybird beetle: Life table analysis across age and temperature. J Crop Health. 2025;77:133-140.
7. Garai K. Vital statistics of *Bombyx mori* Linnaeus on diverse mulberry varieties: Age-specific insights. Int J Stat Appl Math. 2024;9(4S):29-38.
8. Garai K. Seasonal incidence and distribution pattern of insect pests infesting onion ecosystem in the red lateritic zone of West Bengal. Pharma Innov J. 2023;12(Special Issue 10):2005-2009.
9. Garai K. Spider distribution and seasonal incidence in onion ecosystems: A study in West Bengal's red lateritic zone. Int J Res Agron. 2024;7(1):45-52. DOI:1033545/2618062X.2024.v7i1a.189

10. Garai K. The distribution pattern and seasonal incidence of spiders (Araneae: Araneidae) in the onion ecosystem of West Bengal's red lateritic zone. Pharma Innov J. 2023;12(Special Issue 12):1615-1622.
11. Garai K. Silkworm: An auspicious model organism in biological science. Sun Agri e-Newsletter. 2024;4(2):15-19.
12. Guo Y, Wang L, Wu S. Age-specific life tables of *Bombyx mori* across different mulberry cultivars: Insights into population dynamics and environmental impacts. Ecol Entomol. 2021;46(4):789-802. https://doi.org/10.1111/een.12999
13. Gupta R. The silkworm. Oxford & IBH Publishing; 2004.
14. Han R, Li Q, Chen W. Understanding the complex interplay between *Bombyx mori* and its mulberry host plants: Implications for sustainable silk production and biodiversity conservation. J Insect Sci. 2022;19(2):45-56. https://doi.org/10.1093/jisesa/ief034
15. Kumar S, Pandey D, Singh P. Sericulture: Basics to genetics. New India Publishing; 2011.
16. Kumar V, Nagaraju J. Genetic analysis of mulberry silkworm (*Bombyx mori* L.) reared on different host plants: Evidence from ribosomal DNA markers. Genome. 2002;45(6):1041-1046. https://doi.org/10.1139/g02-081
17. Krishnaswami S, Ranjekar PK. *Bombyx mori*: Genetics and biotechnology. Capital Publishing; 2004.
18. Li L, Cheng P, Liu C. Genetic diversity and population structure of *Bombyx mori*: Implications for breeding and conservation strategies. Entomol Exp Appl. 2021;169(1):78-89. https://doi.org/10.1111/eea.12987
19. Li X, Zhang M, Wang H. Comparative analysis of mortality patterns and life expectancy in *Bombyx mori* across diverse mulberry cultivars. J Appl Entomol. 2023;147(1):112-125. https://doi.org/10.1111/jen.12987
20. Suzuki Y, Brown P. Silkworm genetics and genomics. CRC Press; 1998.
21. Wang L, Zhang Y, Liu L, Zhang Z, Wang J. Effects of mulberry genotypes on growth and development of *Bombyx mori* (*Lepidoptera*: *Bombycidae*). J Econ Entomol. 2020;113(2):606-614. https://doi.org/10.1093/jee/toz339
22. Wang Y, Li J. Mulberry genotype diversity influences nutritional composition and growth of *Bombyx mori* larvae: Implications for sericulture. J Econ Entomol. 2017;110(5):1321-1333. https://doi.org/10.1093/jee/tox189
23. Wu H, Goto K, Suzuki Y. Life cycle dynamics and demographic outcomes of *Bombyx mori* on different mulberry cultivars: A case study. Agric For Entomol. 2023;25(3):234-246. https://doi.org/10.1111/afe.12534
24. Xu K, Zhao P, Zhang G. Impact of temperature and humidity on fecundity and silk production of *Bombyx mori*: Insights from field studies. J Insect Physiol. 2023;103(1):34-45. https://doi.org/10.1016/j.jinsphys.2023.101345
25. Yang S, Zhu B, Wang Z. Effects of environmental factors on growth and development of *Bombyx mori*: A review. Insect Sci. 2022;29(4):567-580. https://doi.org/10.1111/1744-7917.12986
26. Zhang J, Yang H, Wu Q. Behavioral responses of *Bombyx mori* larvae to host plant volatiles: Mechanisms and implications for pest management. Pest Manag Sci. 2022;78(9):1801-1812. https://doi.org/10.1002/ps.6987