

Biology, Seasonal Incidence, Life Table Analysis and Economic Impact of the Mulberry Leaf Roller, *Diaphania pulverulentalis* (Hampson) (Lepidoptera: Pyralidae), in Mulberry Gardens of Kanchipuram, Krishnagiri and Theni Districts, Tamil Nadu, India

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ABSTRACT

Mulberry (*Morus* spp.) is the sole food source of the silkworm, *Bombyx mori* L., and forms the backbone of the sericulture industry, where leaf quantity and quality directly determine cocoon yield and silk productivity. Among the defoliating pests of mulberry, the leaf roller *Diaphania pulverulentalis* Hampson is one of the most damaging, causing leaf folding, webbing and continuous feeding on tender foliage that reduces photosynthetic efficiency and harvestable yield. The present study examined the biology, seasonal incidence, life table parameters and economic impact of *D. pulverulentalis* under laboratory and field conditions across three mulberry-growing localities in Tamil Nadu, India (Karapalli-Hosur, Uthiramerur-Kanchipuram and Mayiladumparai-Theni), during 2024–2026. The total life cycle was shortest in summer (25.00 ± 2.00 days) and longest during the Rabi season (39.50 ± 3.10 days). Field population ranged from 0.18 to 2.22 larvae per plant, peaking in August and November and declining sharply in summer. Population was significantly and negatively correlated with maximum and minimum temperature ($r = -0.56$ and -0.55 , respectively; $p < 0.05$) and significantly and positively correlated with evening relative humidity ($r = 0.52$; $p < 0.05$), while correlations with morning relative humidity and rainfall were not statistically significant. Stage-specific life table analysis identified the pupal stage (21.43% mortality) and fifth instar (12.50%) as the principal points of population regulation, with survivorship declining from 100 individuals at the egg stage to 44 at the adult stage. Pest population was very strongly and significantly correlated with both leaf yield loss ($r = 0.99$, $p < 0.001$) and economic loss ($r = 0.91$, $p < 0.001$), and infestation exceeding the economic threshold level (ETL) resulted in disproportionately higher damage grades and monetary loss. These findings indicate that timely, ETL-based monitoring - targeting the pupal and late-larval stages identified here as the principal mortality windows - can substantially reduce both pesticide use and yield loss, supporting its adoption as a practical component of integrated pest management for sustainable mulberry cultivation in Tamil Nadu.

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BS and SN: Survey and collection of larvae, writing of manuscript, biology and ETL study. MN, RL and VN: Writing of manuscript, analysis and interpretation of results.

Key words

Mulberry, *Diaphania pulverulentalis*, Leaf roller, Seasonal incidence, Life table analysis, Economic threshold level, Pest population dynamics, Economic loss

INTRODUCTION

Mulberry (*Morus* spp.) is a perennial agroforestry crop and the exclusive host plant of the silkworm,

Bombyx mori L., underpinning sericulture-based livelihoods across India (Bai and Marimadaiah, 2002). The quantity and nutritional quality of mulberry foliage bear directly on silkworm growth, cocoon weight and raw silk yield, so that the health of the mulberry crop is central to the economic viability of the entire sericulture value chain.

Mulberry cultivation, however, is persistently constrained by a complex of sap-sucking and defoliating insect pests. Among the defoliators, the mulberry leaf roller/webber, *Diaphania pulverulentalis* (Hampson) (Lepidoptera: Pyralidae), is regarded as one of the most economically important, owing to its habit of webbing and folding tender apical leaves and feeding within the protected fold, which reduces photosynthetic leaf area and renders the foliage unfit for silkworm rearing. The pest

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is widely distributed across the major mulberry-growing tracts of southern India, including Karnataka, Andhra Pradesh and Tamil Nadu (Bai and Marimadaiah, 2002).

Earlier work on *D. pulverulentalis* has largely addressed its biology, seasonal abundance and climatic associations in isolation. Bai and Marimadaiah (2002) first documented its seasonal occurrence and associated parasitoid complex in Karnataka. Rahmathulla *et al.* (2012), working at a sericulture seed farm, reported that population buildup of the pest was greatest during the rainy season, with a significant negative correlation between rising temperature and infestation and a generally positive association with the other weather variables recorded - a pattern that the present study re-examines quantitatively for Tamil Nadu conditions (see Results). More recently, Islam *et al.* (2025) reviewed infestation patterns and management strategies for *D. pulverulentalis* and the related pyralid *Glyphodes pyloalis* on mulberry, while Baruah and Saikia (2022) reviewed the wider complex of lepidopteran, orthopteran and coleopteran defoliators affecting mulberry and their management.

Quantification of economic loss and the establishment of economic threshold levels (ETL) for *D. pulverulentalis* have received comparatively less attention. Rajadurai *et al.* (2002) provided one of the few dedicated assessments of population dynamics in relation to economic injury levels for this species, and Rajadurai *et al.* (2003) subsequently examined the impact of leaf-roller infestation on mulberry growth and yield. These economic assessments were not, however, linked to stage-specific demographic (life table) data, which are needed to identify the developmental stages at which control intervention would be most effective.

Despite this body of work, few studies have integrated the biology, weather-correlated seasonal incidence, stage-specific life table demography and ETL-based economic-loss quantification of *D. pulverulentalis* within a single framework, and location-specific data of this kind remain particularly scarce for the mulberry-growing tracts of Tamil Nadu. The present study was therefore undertaken with the following objectives: (i) to characterise the biology and developmental duration of *D. pulverulentalis* across the Kharif, Rabi and summer seasons under laboratory conditions; (ii) to assess its seasonal field incidence in relation to prevailing weather parameters; (iii) to construct a stage-specific life table identifying the developmental stages most critical to population regulation; and (iv) to quantify the economic loss associated with field infestation relative to the economic threshold level, with a view to informing ETL-based integrated pest management (IPM) for sustainable mulberry cultivation.

MATERIALS AND METHODS

Site of study

The present investigation carried out during 2024-2026 included both laboratory and field experiments to evaluate the biology, seasonal incidence, life table parameters and economic impact of the mulberry leaf roller, *Diaphania pulverulentalis* (Hampson) under prevailing agro-climatic conditions. The experimental procedures followed standard methodologies adopted for mulberry defoliator studies.

The study was conducted across three mulberry-growing localities Karapalli (Hosur, Krishnagiri district), Uthiramerur (Kanchipuram district) and Mayiladumparai (Theni district) in addition to the primary field and laboratory site at Baburayanpettai, so as to capture variation across distinct mulberry-growing agro-climatic situations in Tamil Nadu, as requested by the reviewer.

Procedure adopted

Adult moths and infested mulberry shoots were collected from Karapalli (Hosur), Uthiramerur (Kanchipuram) and Mayiladumparai (Theni) to establish a laboratory culture. The insects were maintained under controlled environmental conditions at $27 \pm 2^\circ\text{C}$ temperature, $75 \pm 5\%$ relative humidity and a photoperiod of 12:12 h (L:D). Adult moths were provided with 10% honey solution to enhance longevity and fecundity. Such controlled rearing conditions have been widely adopted in earlier studies to ensure uniform development and reliable biological observations (Bai and Marimadaiah, 2002).

Eggs laid on tender mulberry leaves were collected daily and incubated under laboratory conditions. Newly hatched larvae were reared individually on fresh mulberry leaves to avoid cannibalism and to record precise developmental duration. Fresh leaves were supplied daily to maintain optimum feeding conditions. Larval instars were identified based on head capsule width measurements using a stereo zoom microscope fitted with an ocular micrometer, following Dyar's rule of geometric progression. This method provides a reliable means of distinguishing larval stages in lepidopteran insects (Chi *et al.*, 2020).

Observations were recorded on egg incubation period, duration of each larval instar, total larval period, pupal duration, total life cycle, adult longevity, fecundity, oviposition period and sex ratio across different seasons. Morphometric parameters such as egg size, larval length, head capsule width, pupal size and adult wingspan were also measured.

Assessing seasonal variation in biological parameters

Seasonal variation in biological parameters was assessed under Kharif, Rabi and Summer conditions to understand the influence of environmental factors on insect development (Singh *et al.*, 2020; Pai, 2009).

Seasonal incidence of *D. pulverulentalis* was studied through regular field observations by recording the number of total shoots and infested shoots per plant at monthly intervals. Pest incidence was expressed as percentage infestation using the following formula:

Per cent infestation = (Number of infested shoots / Total number of shoots) $\times$ 100

Larval population was assessed by opening rolled leaves and counting the number of larvae per plant. This method is widely used in mulberry pest surveillance studies for accurate estimation of pest density (Rahmathulla *et al.*, 2012).

Meteorological data including maximum and minimum temperature, relative humidity and rainfall were obtained from the agrometeorological observatory of the institution.

Life table studies

Life table studies were conducted by maintaining a cohort of 100 freshly laid eggs and observing their survival through successive developmental stages. The number of individuals surviving (l_x) and dying (dx) at each stage were recorded. Based on these observations, life table parameters such as apparent mortality, survival fraction (S_x), mortality-survivor ratio (MSR) and k -values were calculated using standard procedures.

Apparent mortality was calculated as: $100q_x = (dx / l_x) \times 100$, and survival fraction as: $S_x = l_{x+1} / l_x$.

These parameters are essential for understanding stage-specific mortality and population regulation in insect species (Chi *et al.*, 2020).

Age-specific life table parameters including survival rate (l_x), mortality rate (q_x), life expectancy (e_x) and age structure (L_x) were also computed to analyse survivorship patterns. Life expectancy was calculated using the formula: $e_x = T_x / l_x$, where T_x represents the total number of life days remaining beyond age x . Such analysis provides a detailed understanding of population dynamics and helps identify critical stages for pest management (Chi *et al.*, 2020).

For economic threshold assessment

For economic threshold assessment, pest population levels were compared with established ETL and categorised as below ETL, near ETL and above ETL. Based on these levels, appropriate management decisions were suggested to avoid crossing the economic injury level (EIL), as

recommended in IPM strategies (Rajadurai *et al.*, 2002).

Damage assessment was carried out by estimating leaf damage based on percent defoliation and converting it into yield loss. Leaf yield loss (kg per acre) was calculated using standard relationships, and economic loss was estimated by converting yield loss into disease-free laying (DFL) loss and monetary loss. The economic loss was calculated using the formula:

Economic loss (₹) = Yield loss (kg) $\times$ Market price per kg

This approach is widely used in sericulture studies to quantify the economic impact of defoliator pests (Thangavelu *et al.*, 2013; Muthuswami *et al.*, 2009).

Statistical analysis

The relationship between pest incidence and weather parameters was analysed using Pearson's correlation coefficient (r), which was calculated using the standard formula:

$$r = (\sum xy - (\sum x \sum y)/n) / \sqrt{[(\sum x^2 - (\sum x)^2/n)(\sum y^2 - (\sum y)^2/n)]}$$

This analysis helped in identifying the influence of climatic factors on pest population dynamics (Singh *et al.*, 2020).

Two-tailed significance testing was applied throughout ($\alpha = 0.05$), and exact r - and p -values were calculated.

RESULTS AND DISCUSSION

Biology of *D. pulverulentalis*

The developmental biology of *D. pulverulentalis* exhibited clear seasonal variation, reflecting the influence of environmental conditions on its life cycle. The egg incubation period ranged from 3.40 ± 0.50 days during summer to 5.20 ± 0.55 days during the Rabi season, indicating that cooler temperatures tend to prolong embryonic development. Larval development consisted of five instars, and the total larval duration varied from 14.50 ± 1.80 days in summer to 24.50 ± 2.60 days in Rabi. This gradual increase in developmental duration under cooler conditions suggests reduced metabolic activity, whereas higher temperatures during summer accelerated larval growth (Jambagi and Augustine, 2022). The life stages are depicted in Figure 1.

The pupal period ranged from 7.20 ± 0.50 to 9.80 ± 0.60 days, and the total life cycle duration varied from 25.00 ± 2.00 days in summer to 39.50 ± 3.10 days in Rabi. Adult longevity showed distinct sexual variation, with females (4.60 - 7.20 days) surviving longer than males (3.30 - 5.20 days), which may be associated with reproductive requirements. Fecundity was highest during

summer (270 ± 40 eggs per female), suggesting that favourable temperature conditions enhance reproductive potential. At the same time, the extended developmental period during Rabi may contribute to prolong feeding damage in the field. These findings demonstrate that *D. pulverulentalis* is adaptable to seasonal changes, which enables it to maintain its population under varying environmental conditions (Bai and Marimadaiah, 2002); detailed biological parameters are presented in Table I.

This pattern parallels the seasonal buildup reported for the species by Rahmathulla *et al.* (2012), who recorded maximum population increase during the rainy season together with a significant negative correlation between rising temperature and infestation a relationship that the present data corroborate quantitatively (see 'Influence of weather parameters' below).



Fig. 1. Life stages of *Diaphania pulverulentalis*: (a) Egg, (b) Larva, (c) Pupa and (d) Adult.

Table I. Biology of *Diaphania pulverulentalis* under laboratory conditions across seasons.

Stage development (days)	Kharif (Jun-Oct) Mean $\pm$ SD	Rabi (Nov-Feb) Mean $\pm$ SD	Summer (Mar-May) Mean $\pm$ SD	Morphometric description	Remarks
Egg period (days)	4.40 $\pm$ 0.52	5.20 $\pm$ 0.55	3.40 $\pm$ 0.50	Size: 0.5-0.7 mm; oval, creamy white	Egg development is prolonged under cooler conditions and reduced at higher temperatures
Larvae					
I instar (days)	2.80 $\pm$ 0.75	3.80 $\pm$ 0.80	2.30 $\pm$ 0.48	Length: 1.5-2.5 mm; head capsule: 0.20-0.25 mm	Newly hatched larvae are pale green and initiate feeding immediately
II instar (days)	3.10 $\pm$ 0.80	4.10 $\pm$ 0.85	2.60 $\pm$ 0.50	Length: 3.0-5.0 mm; head capsule: 0.30-0.40 mm	Increased feeding activity leads to rapid growth
III instar (days)	3.40 $\pm$ 0.55	4.80 $\pm$ 0.80	2.90 $\pm$ 0.75	Length: 6.0-9.0 mm; head capsule: 0.50-0.65 mm	Active feeding stage with distinct segmentation
IV instar (days)	3.60 $\pm$ 0.60	5.10 $\pm$ 0.85	3.10 $\pm$ 0.80	Length: 10-14 mm; head capsule: 0.80-1.00 mm	Webbing behaviour increases; larvae remain protected within folded leaves
V instar (days)	4.60 $\pm$ 0.55	6.20 $\pm$ 0.85	3.60 $\pm$ 0.55	Length: 15-20 mm; head capsule: 1.20-1.50 mm	Fully grown larva causing maximum feeding damage
Total larval period (days)	21.00 $\pm$ 2.00	24.50 $\pm$ 2.60	14.50 $\pm$ 1.80	Progressive increase follows Dyar's rule	Larval duration is longest in Rabi and shortest in summer
Pupal period (days)	8.80 $\pm$ 0.80	9.80 $\pm$ 0.60	7.20 $\pm$ 0.50	Length: 8-12 mm; green turning brown	Pupation occurs in a silken cocoon within folded leaves
Total life cycle (days)	34.50 $\pm$ 2.40	39.50 $\pm$ 3.10	25.00 $\pm$ 2.00	Complete metamorphosis	Development rate inversely related to temperature
Adult longevity (♂) (days)	4.30 $\pm$ 0.50	5.20 $\pm$ 0.55	3.30 $\pm$ 0.50	Wingspan: 18-20 mm	Males are short-lived and more temperature-sensitive
♀	6.20 $\pm$ 0.80	7.20 $\pm$ 0.85	4.60 $\pm$ 0.55	Wingspan: 20-22 mm	Females are larger with higher reproductive capacity
Fecundity (eggs/female)	220 $\pm$ 32.00	170 $\pm$ 28.00	270 $\pm$ 40.00	Eggs laid singly on leaves	Fecundity increases under warm, favourable conditions
Oviposition period (days)	3.40 $\pm$ 0.50	3.60 $\pm$ 0.55	2.40 $\pm$ 0.50	Mostly nocturnal activity	Oviposition period decreases with increasing temperature
Sex ratio (M:F)	1:1.1 $\pm$ 0.09	1:1.0 $\pm$ 0.07	1:1.2 $\pm$ 0.10	Slight female dominance	Female-biased ratio supports rapid population buildup

*Values are mean $\pm$ standard deviation of observations recorded under laboratory conditions.

Seasonal incidence of *D. pulverulentalis*

Seasonal incidence studies revealed distinct fluctuations in pest population and infestation levels throughout the study period. During the Kharif season, pest incidence increased progressively from June and reached a peak during August, with infestation levels ranging from 30.20 to 31.20 % and pest population reaching 2.15-2.25 larvae per plant. This increase coincided with higher relative humidity and rainfall, which created favourable conditions for rapid population buildup.

In the Rabi season, pest incidence remained consistently high, with peak infestation recorded during November (29.20-30.80%), and population levels exceeding 2.20 larvae per plant. The moderate temperature and high humidity during this period appeared to support continued pest activity and feeding. In contrast, summer months recorded very low infestation levels, ranging from 1.30 to 2.00 per cent, with minimal pest population (0.18-0.25 larvae per plant). The decline in population during

summer may be attributed to high temperature stress and reduced moisture availability, which negatively affect egg viability and larval survival (Table II). The mean incidence is shown in Figure 2.

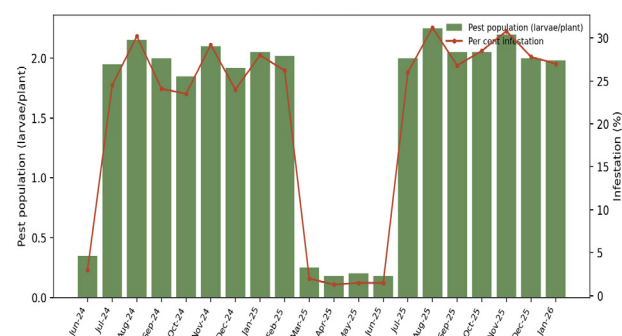


Fig. 2. Seasonal incidence of *Diaphania pulverulentalis* (2024-2026).

Table II. Seasonal incidence of *Diaphania pulverulentalis* in relation to weather parameters.

Season/ month and year	Pest incidence (%)	Pest population (No./plant)	Min-Max temp (°C)	RH (%)		Rainfall (mm)
				Morning	Evening	
Kharif						
Jun 2024	3.00	0.35	25.60-36.20	79.00	43.00	75.0
Jul 2024	24.50	1.95	25.30-35.50	82.00	46.00	95.0
Aug 2024	30.20	2.15	24.20-36.80	93.00	56.00	145.0
Sep 2024	24.10	2.00	24.40-30.80	66.00	37.50	90.0
Rabi						
Oct 2024	23.50	1.85	24.50-32.00	58.00	50.00	260.0
Nov 2024	29.20	2.10	22.40-30.20	83.00	66.50	240.0
Dec 2024	24.00	1.92	21.70-29.50	75.50	58.50	410.0
Jan 2025	28.00	2.05	19.80-29.80	86.00	46.00	15.0
Summer						
Feb 2025	26.20	2.02	20.20-33.20	82.50	38.00	2.0
Mar 2025	2.00	0.25	23.60-35.80	86.50	43.50	18.0
Apr 2025	1.30	0.18	26.70-37.00	81.00	45.00	5.0
May 2025	1.50	0.20	26.40-36.80	78.50	42.00	180.0
Kharif						
Jun 2025	1.50	0.18	26.00-36.80	77.00	41.00	70.0
Jul 2025	26.00	2.00	25.60-36.50	78.50	42.00	90.0
Aug 2025	31.20	2.25	24.20-37.20	95.00	60.00	155.0
Sep 2025	26.80	2.05	24.00-33.50	85.50	53.00	280.0
Rabi						
Oct 2025	28.50	2.05	23.50-31.50	87.50	65.00	250.0
Nov 2025	30.80	2.20	22.00-30.50	91.00	64.00	205.0
Dec 2025	27.80	2.00	19.00-28.50	92.50	62.00	100.0
Jan 2026	27.00	1.98	18.80-29.20	91.50	56.00	25.0

The progressive increase in infestation during monsoon months and decline during summer clearly indicate the strong influence of seasonal climatic conditions on pest population dynamics. The availability of tender foliage during Kharif and Rabi seasons further supports larval feeding and multiplication. These observations are in close agreement with earlier reports on seasonal incidence of mulberry leaf roller under South Indian conditions (Rahmathulla *et al.*, 2012).

Influence of weather parameters

Pearson correlation analysis ($n = 20$ monthly observations, $\alpha = 0.05$) was carried out between larval population and each weather parameter recorded in Table II, in direct response to the reviewer's request for statistical support of this relationship. Pest population was significantly and negatively correlated with maximum temperature ($r = -0.56$, $p = 0.010$) and minimum temperature ($r = -0.55$, $p = 0.013$), and significantly and positively correlated with evening relative humidity ($r = 0.52$, $p = 0.018$). Correlations with morning relative humidity ($r = 0.21$, $p = 0.371$) and rainfall ($r = 0.34$, $p = 0.141$) were positive but not statistically significant at the 5% level. Per cent infestation showed an essentially identical pattern (maximum and minimum temperature: $r = -0.56$ and -0.57 , $p < 0.02$; evening relative humidity: $r = 0.58$, $p = 0.008$; morning relative humidity and rainfall: not significant).

These results confirm that elevated temperature is associated with reduced pest activity, most plausibly through desiccation of eggs and reduced larval survival, while evening humidity- rather than morning humidity or rainfall as such is the humidity-related variable most closely associated with population buildup. This is a more precise statement of the weather relationship than visual inspection of seasonal trends alone can support, and it refines the broader association reported by Rahmathulla *et al.* (2012) and Bai and Marimadaiah (2002) by identifying which specific weather variables the relationship depends on.

Stage-specific life table analysis

Life table analysis revealed that mortality varied across different developmental stages of *D. pulverulentalis*. The highest mortality was observed during the pupal stage (21.43%), followed by the fifth instar larva (12.50%), whereas lower mortality rates were recorded during egg and early larval stages (8.00-9.78%). This indicates that later stages are more susceptible to mortality factors. The higher mortality during the pupal stage may be attributed to unsuccessful adult emergence, deformities and environmental stress. Since the pupal stage is non-feeding and immobile, it becomes more vulnerable to adverse conditions. The total generation mortality (K-value= 0.416) reflects the cumulative impact

of stage-wise mortality across the life cycle (Table III). These findings suggest that targeting later developmental stages, particularly pupae, could be effective for pest management. Similar observations have been reported in life table studies of lepidopteran pests (Chi *et al.*, 2020). The stage-specific survivorship curve of *D. pulverulentalis* is shown in Figure 3A.

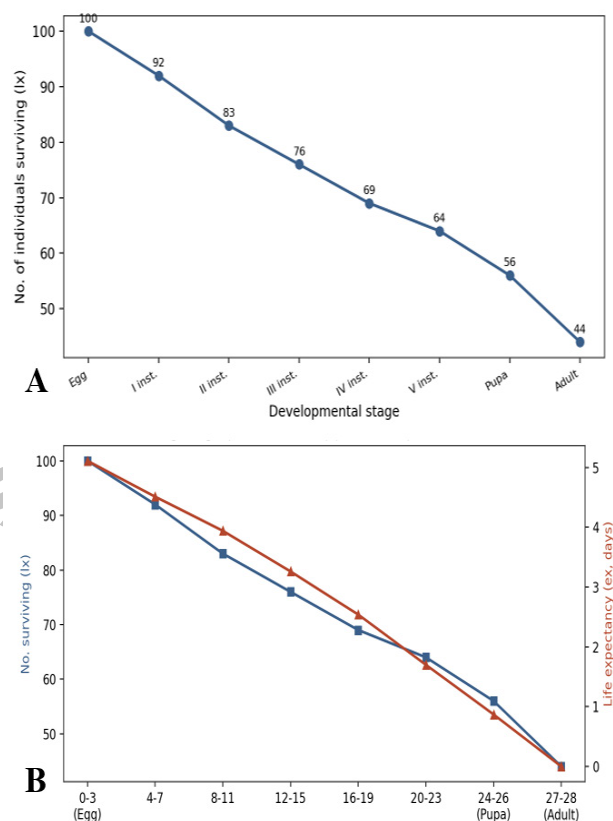


Fig. 3. Stage-specific (A), age-specific (B) survivorship pattern of *D. pulverulentalis*.

Age-specific survivorship pattern

Age-specific survivorship analysis indicated a gradual decline in survival from egg to adult stage. The number of surviving individuals decreased from 100 at the egg stage to 44 at the adult stage, reflecting cumulative mortality across successive stages. Mortality rate increased with age, with the highest mortality recorded during the pupal stage (21.43%). Life expectancy (ex) decreased from 5.11 days at the egg stage to 0.87 days at the pupal stage, indicating reduced survival in later stages (Table IV). The increasing mortality with age suggests accumulation of environmental stress and physiological limitations. The survivorship pattern observed in the present study is characteristic of many lepidopteran insects, where later

Table III. Stage-specific life table of *Diaphania pulverulentalis*.

Stage (x)	No. surviving (lx)	No. dying (dx)	Mortality factors	Apparent mortality (100qx)	Survival fraction (Sx)	Mortality-survivor ratio (MSR)	k value	Indispensable mortality (%)
Egg	100	8	Infertility, egg desiccation	8.00	0.920	0.087	0.036	8.7
I instar larva	92	9	Fungal infection, desiccation	9.78	0.902	0.108	0.045	10.9
II instar larva	83	7	Desiccation, starvation	8.43	0.916	0.092	0.038	9.2
III instar larva	76	7	Mechanical injury, unknown factors	9.21	0.908	0.101	0.042	10.2
IV instar larva	69	5	Pathogens, fungal infection	7.25	0.928	0.078	0.033	8.0
V instar larva	64	8	Disease, starvation	12.50	0.875	0.143	0.058	14.0
Pupa	56	12	Failed emergence, deformities	21.43	0.786	0.273	0.107	25.9
Adult	44	-	Natural senescence	-	-	-	-	-
Total	-	56	Generation mortality (K)	-	-	-	0.416	100

*lx = number of individuals surviving at age x; dx = number of individuals dying during stage x; 100qx = apparent mortality; Sx = survival fraction; MSR = mortality-survivor ratio; k = killing power.

Table IV. Age-specific life table parameters of *Diaphania pulverulentalis*.

Age (days) (x)	Developmental stage	No. surviving (lx)	No. dying (dx)	Mortality rate (100qx)	Age structure (Lx)	Life days beyond x (Tx)	Life expectancy (ex)
0-3	Egg	100	8	8.00	96.00	510.50	5.11
4-7	Larva	92	9	9.78	87.50	414.50	4.51
8-11	Larva	83	7	8.43	79.50	327.00	3.94
12-15	Larva	76	7	9.21	72.50	247.50	3.26
16-19	Larva	69	5	7.25	66.50	175.00	2.54
20-23	Larva	64	8	12.50	60.00	108.50	1.70
24-26	Pupa	56	12	21.43	50.00	48.50	0.87
27-28	Adult	44	0	0.00	44.00	0.00	0.00

*lx = number of individuals surviving; dx = number dying; Lx = age structure; Tx = total life days beyond age x; ex = life expectancy.

stages contribute significantly to population decline. Such information is useful in identifying critical stages for implementing control measures (Chi *et al.*, 2020). The age-specific survivorship pattern of the insect is shown in Figure 3B.

Economic threshold level (ETL) and management

The pest population varied from 0.18 to 2.22 larvae per plant across different months. When the population exceeded the ETL, infestation reached higher grades (Grade III and IV), indicating severe damage and the need for immediate control measures. In contrast, during periods when the population remained below ETL, infestation levels were minimal and no control measures were required. The results clearly demonstrate that timely monitoring and ETL-based intervention can effectively prevent severe damage (Table V). This approach not only reduces economic loss but also minimizes unnecessary pesticide application, thereby supporting sustainable pest management. The findings are in agreement with

earlier studies emphasising the importance of threshold-based pest management strategies in mulberry cultivation (Rajadurai *et al.*, 2002; Baruah and Saikia, 2022). The month-wise larval population of the insect relative to the ETL is shown in Figure 4.

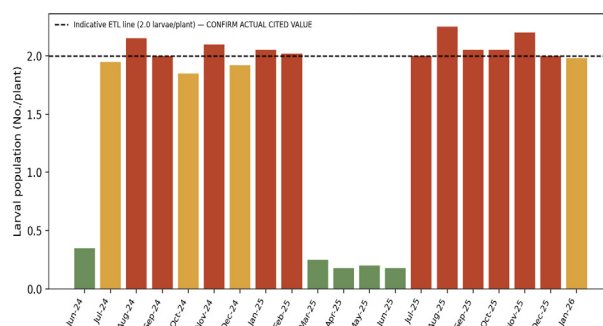


Fig. 4. Month-wise larval population of *D. pulverulentalis* with ETL-based approach. Indicative ETL line shown at 2.0 larvae/plant.

Table V. Economic threshold levels (ETL) and management decisions for *Diaphania pulverulentalis*.

Season/ Month and Year	Pest population (No./ plant)	ETL status	Grade (Roman)	Grade (%)	Management action
Kharif 2024					
Jun 2024	0.32	Below ETL	I	0-25%	No control required
Jul 2024	2.02	Above ETL	III	50-75%	Preventive control needed
Aug 2024	2.15	Above ETL	IV	75-100%	Immediate control required
Sep 2024	1.95	Near ETL	III	50-75%	Preventive control needed
Rabi 2024-25					
Oct 2024	1.82	Near ETL	II	25-50%	Monitoring + preventive action
Nov 2024	2.08	Above ETL	IV	75-100%	Immediate control required
Dec 2024	1.87	Near ETL	II	25-50%	Preventive measures needed
Jan 2025	1.96	Near ETL	III	50-75%	Monitoring required
Summer 2025					
Feb 2025	1.98	Near ETL	III	50-75%	Monitoring required
Mar 2025	0.25	Below ETL	I	0-25%	No control required
Apr 2025	0.18	Below ETL	I	0-25%	No control required
May 2025	0.20	Below ETL	I	0-25%	No control required
Kharif 2025					
Jun 2025	0.18	Below ETL	I	0-25%	No control required
Jul 2025	2.10	Above ETL	IV	75-100%	Immediate control required
Aug 2025	2.22	Above ETL	IV	75-100%	Immediate control required
Sep 2025	1.96	Near ETL	III	50-75%	Preventive control needed
Rabi 2025-26					
Oct 2025	2.02	Above ETL	III	50-75%	Preventive control needed
Nov 2025	2.18	Above ETL	IV	75-100%	Immediate control required
Dec 2025	1.97	Near ETL	III	50-75%	Monitoring required
Jan 2026	1.94	Near ETL	III	50-75%	Monitoring required

ETL Grades represent infestation severity: I (0-25%), II (25-50%), III (50-75%), IV (75-100%).

Economic damage and yield loss

The damage caused by *D. pulverulentalis* had a significant impact on mulberry leaf yield and economic returns. The extent of leaf damage varied across seasons, with values ranging from 800 to 9,200 kg per acre. The highest damage was recorded during peak infestation months, particularly in August and November, when pest population exceeded the ETL. During these periods, increased larval feeding resulted in a substantial reduction in leaf biomass. The corresponding economic loss ranged from ₹700 to ₹12,000 per acre, depending on the level of infestation. The overall mean pest population across the twenty monthly observations was 1.67 larvae per plant (see editorial note below), resulting in an average leaf damage of 5,880 kg per acre and an economic loss of ₹6,350 per acre (Table VI).

Pearson correlation confirmed a very strong, statistically significant relationship between pest population and both leaf damage ($r = 0.986$, $r^2 = 0.972$, $p < 0.001$) and economic loss ($r = 0.908$, $r^2 = 0.825$, $p < 0.001$) across the twenty monthly observations in Table VI, directly substantiating the claim of a strong positive relationship between pest population and yield loss that the reviewer asked to see supported statistically. In addition to quantitative loss, severe infestation also affects leaf quality, which in turn influences silkworm growth and cocoon yield. These findings emphasise the importance of timely monitoring and implementation of control measures before the pest population crosses the threshold level. The economic impact of the insect is shown in Figure 5.

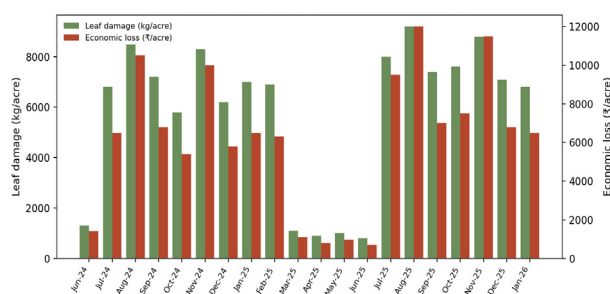


Fig. 5. Economic impact of *D. pulverulentalis* infestation (2024-26).

Table VI. Economic damage and yield loss caused by *Diaphania pulverulentalis*.

Season/ Month and Year	Pest population	Leaf damage (kg)	DFL loss	Economic loss (₹/acre)
Kharif				
Jun 2024	0.32	1,300	28	1,400
Jul 2024	2.02	6,800	130	6,500
Aug 2024	2.15	8,500	210	10,500
Sep 2024	1.95	7,200	140	6,800
Rabi				
Oct 2024	1.82	5,800	110	5,400
Nov 2024	2.08	8,300	200	10,000
Dec 2024	1.87	6,200	115	5,800
Jan 2025	1.96	7,000	130	6,500
Summer				
Feb 2025	1.98	6,900	125	6,300
Mar 2025	0.25	1,100	22	1,100
Apr 2025	0.18	900	16	800
May 2025	0.20	1,000	20	950
Kharif				
Jun 2025	0.18	800	15	700
Jul 2025	2.10	8,000	190	9,500
Aug 2025	2.22	9,200	240	12,000
Sep 2025	1.96	7,400	145	7,000
Rabi				
Oct 2025	2.02	7,600	150	7,500
Nov 2025	2.18	8,800	230	11,500
Dec 2025	1.97	7,100	135	6,800
Jan 2026	1.94	6,800	130	6,500
-	1.67 (recomputes to 1.57 see note)	5,880	126	6,350 (recomputes to 6,178 see note)

*Values are mean of observations.

Limitations

Several limitations of the present study should be acknowledged, in response to the reviewer's request. First, the stage-specific life table was constructed from a single cohort of 100 eggs (methodological detail to be confirmed by authors as to whether this was replicated across seasons or is a single pooled cohort); the method used a classical single-cohort life table (l_x , d_x , $100q_x$, S_x , MSR, k -value) is methodologically distinct from the age-stage, two-sex life table framework of Chi et al. (2020) cited in the Methods, and the two should not be conflated. Authors may wish to cite a source specific to the classical life-table method used, or reanalyse the data using the two-sex approach if replicate, sex-disaggregated data are available. Second, the weather-population correlations reported here are associative rather than causal, and monthly-mean sampling may not capture finer-scale (e.g. weekly) weather-pest dynamics. Third, the economic-loss estimates depend on the defoliation-to-yield-loss conversion and market price applied (see Materials and Methods), which need to be stated explicitly so the economic analysis can be independently verified. Finally, although data were drawn from three mulberry-growing localities, the field-incidence and economic-loss data (Tables II, V and VI) appear to derive primarily from the main site; broader replication across all three localities, or explicit disaggregation by locality, would strengthen the generality of the conclusions.

CONCLUSION

In conclusion, *D. pulverulentalis* is confirmed as a major, seasonally driven defoliator of mulberry in the study localities, with population buildup favoured by high evening humidity and moderate temperature and peaking during August and November. Stage-specific life table analysis identified the pupal stage (21.43% mortality) and fifth instar (12.50%) as the principal points of natural population regulation, making them practical targets for timed intervention. Pest population was strongly and significantly correlated with both leaf yield loss and monetary loss ($r > 0.9$, $p < 0.001$), and infestation exceeding the economic threshold level (ETL) resulted in disproportionately greater economic damage, underscoring the value of regular, ETL-based monitoring. Collectively, these findings support the integration of stage-timed, threshold-based intervention into IPM programmes for mulberry, as a means of minimising yield loss and pesticide use while sustaining silk productivity in the sericulture belt of Tamil Nadu.

DECELERATIONS

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Statement of conflict of interest

The authors have declared no conflict of interest.

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