Original Research Article

Assessment of stable strains of Eri silkworms (*Samia ricini*) for commercial silk production under the climate of Manipur

Abstract

Aims: This study evaluates the performance of six Eri silkworm (*Samia ricini*) strains across multiple quantitative traits to identify the most suitable rearing period and stable strains for commercial silk production in Northeast India.

Study Design: A field experiment was conducted to assessed the productivity and stability of different Eri silkworm strains across four seasons.

Place and Duration of Study: The study was carried out in Imphal, Manipur, over four different rearing seasons.

Methodology: Six Eri silkworm strains were evaluated for eight quantitative traits, hatching percentage, fecundity, effective rate of rearing, larval weight, pupation rate, single shell weight, single cocoon weight and shell percentage. Data were collected across four seasons, and hierarchical clustering analysis was performed to classify the strains based on genetic and phenotypic similarities.

Results: The findings indicate that the April-May season provides optimal rearing conditions, resulting in higher survival rates, improved fecundity, and superior silk yield compared to other seasons. The Yellow Zebra strain performed consistently across multiple attributes and seasons, showing the highest stability among the strains that were studied. Hierarchical clustering analysis grouped the strains into three distinct clusters, reflecting their genetic and phenotypic relationships.

Conclusion: The identification of stable strains and optimal rearing periods is crucial for enhancing Eri silkworm productivity and sustainability. These findings provide a scientific basis for strain selection and breeding strategies, benefiting both farmers and researchers involved in Eri silk production.

Keywords: *Eri silkworm, Strains, Seasonal Performance, Hierarchical Clustering, Sericulture.*

1. INTRODUCTION

Sericulture is broadly classified into two distinct types *viz*., mulberry sericulture which feeds on the mulberry leaves (*Morus* sp.), and non-mulberry/Vanya sericulture which includes Tasar, Oak Tasar, Eri, and Muga culture. Among them, the Eri silkworm (*Samia ricini*) is one of the most important non-mulberry silkworm species, primarily reared in Northeast India, including Manipur, Assam, and Meghalaya. It is a multivoltine, polyphagous silkworm species with several morphotypes with twenty-six eco-races identified. There are a total of 19 species of Eri (genus *Samia*) worldwide, of which only four species are reported from India (Arora and Gupta, 1979). Among these, two species are found in the northeastern region, *i.e*., *Samia canningi* and *Samia ricini*. Eri silkworm plays a crucial role in rural livelihoods due to its ability to feed on castor (*Ricinus communis*), making it a versatile and easy-to-rear silkworm species (Debaraj *et al.,* 2022). However, the productivity and quality of Eri silk are influenced by multiple factors, including genetic variability, environmental conditions and seasonal fluctuations, necessitating a comprehensive evaluation of Eri silkworm strains under diverse climatic conditions (Halagundegowda *et al.,* 2023). Seasonal variations play a crucial role in determining the performance of Eri silkworm strains. The fluctuations in temperature, humidity and photoperiod influence silkworm physiology, affecting their growth and economic traits. Identifying the most stable strains across different seasons is vital for optimizing silk production and ensuring sustainable sericulture practices in the region. Previous studies have indicated that certain strains exhibit better adaptability to environmental conditions, making them more suitable for large-scale commercial rearing (Priyanki and Jogen, 2013). Shifa *et al.,(*2015) also mentioned the importance of selection and utilization of the best suited strains of eri silkworm race that adapt to the varied ecological condition will help in increasing their productivity. However, a detailed cluster analysis and interaction study to classify these strains based on performance stability across seasons is still lacking. The current study was carried out in Imphal, Manipur, to assess six strains of Eri silkworms according to their quantitative characteristics throughout the course of four seasons to determine the ideal rearing season and strain to maximize silk production.

2.MATERIALS AND METHODS

The experiment was conducted at Regional Sericultural Research Station (RSRS), Central Silk Board, Imphal East, Manipur, India (latitude 24.82°N, longitude 93.95°E, altitude 786 meters above sea level). Manipur experiences a subtropical monsoon climate characterized by distinct seasonal variations in temperature, humidity, and rainfall, influencing Eri silkworm rearing conditions. The study was carried out across four seasons such as March–April, April–May, May-June, and June-July (Table 2) to evaluate the six Eri silkworm strains, Greenish Blue Plain (GBP), Greenish Blue Zebra (GBZ), Greenish Blue Spotted (GBS), Yellow Plain (YP), Yellow Zebra (YZ), and Yellow Spotted (YS) (Table 1). The silkworm eggs were supplied from RSRS, Imphal and were reared under optimal environmental conditions suggested by Oduor *et al*., (2016). A randomized block design (RBD) with three replications was employed to assess the seasonal performance of silkworm strains. Each replication consisted of 200 larvae per strain, with a total of 3600 larvae across all treatments. According to Debaraj *et al.,* (2001), data were recorded for all quantitative traits such as fecundity, Hatching (%), Larvae Weight (g), Effective Rate of Rearing (ERR%), Pupation Rate, Single Cocoon Weight (SCW), Single Shell Weight (SSW), shell percentage (SR%). The collected data were analysed using R (version 4.2.2) (R Core Team, 2024).

Table 1: Representation of characteristic features of Eri silkworm strains for comparative rearing for the study

SL.NO.	STRAINS	MARKING TYPE	COLOUR
1	Yellow Plain (YP)	Plain	Yellow
2	Yellow Spotted (YS)	Black Spot	Yellow
3	Yellow zebra (YZ)	Zebra strips	Yellow
4	Greenish Blue Plain (GBP)	Plain	Greenish
5	Greenish Blue Spotted (GBS)	Black Spot	Greenish
6	Greenish Blue Zebra (GBZ)	Zebra strips	Greenish

Table 2: Temperature and Relative Humidity conditions during four seasons of the study period in Manipur

SEASONS	TEMPERATURE (°C)			RELATIVE HUMIDITY (%)		
	MINIMUM	MAXIMUM	AVERAGE	MINIMUM	MAXIMUM	AVERAGE
(March-april)	15.9	28.5	22.2	42.8	98.0	78
(April-may)	15.7	30.1	22.9	54.8	99.7	88.7
(May-june)	18.0	30.4	24.2	65.0	99.8	90.4
(June-july)	20.2	32.4	26.3	60.5	99.6	88.1

3. RESULTS

3.1 Eri silkworm strains and rearing performance

The investigation began with collecting the dfls of six silkworm strains with different physical characteristic features for rearing throughout the year. Since Manipur is located in the subtropical region it observes four seasons for rearing eri silkworm crop. The temperature and humidity data were collected for the entire silkworm crop which includes from brushing to spinning for each season (Table 2). The data was subjected to descriptive statistics, which (Table 3) revealed significant seasonal variations in economic traits *viz*., cocoon weight and shell weight. The mean hatchability percentage

Table 3: Descriptive Statistics of Quantitative Traits in Eri Silkworm Strains Across Season

STRAINS	SEASON	HA%	FEC	LW(g)	ERR%	PR	SSW(g)	SCW(g)	SR
Y P	March-April	96.87	482	9.32	88	97.32	0.455	3.235	14.06
Y S		95.78	414	9.27	81	91.3	0.43	2.98	14.43
Y Z		95.91	465	9.24	90	98.07	0.455	3.26	13.96
G B P		95.02	442	8.96	79	97.93	0.485	3.475	13.6
G B S		95.53	403	9.37	85	93.84	0.445	3.09	14.40
G B Z		96.5	429	9.19	87	97.93	0.405	3.09	13.11
Y P	April-May	95.55	427	10.17	92	96.65	0.585	3.815	15.33
Y S		97.08	411	10.38	80	92.14	0.595	4.17	14.27
Y Z		95.38	455	10.39	93	97.42	0.64	4.27	14.99
G B P		96.57	438	9.89	89	93.46	0.59	3.765	15.67
G B S		96.19	447	9.55	87	95.73	0.585	4.145	14.11
G B Z		96.01	452	11	85	90.12	0.625	3.98	15.70
Y P	May-June	97.29	396	9.89	94	97.13	0.645	3.985	16.19
Y S		95.22	379	10.11	86	96.56	0.615	3.71	16.56
Y Z		95.49	360	10.23	93	93.42	0.63	4.005	15.73
G B P		95.93	307	9.86	88	95.37	0.6	3.775	15.89
G B S		96.77	360	9.51	89	92.14	0.535	3.725	14.36
G B Z		95.83	414	10.61	87	90.42	0.605	3.985	15.18
Y P	June-July	84.21	418	9.84	92	91.37	0.525	3.89	13.50
Y S		89.9	389	10.96	86	90.02	0.69	3.86	17.88
Y Z		91.52	341	9.87	94	87.42	0.605	3.795	15.94
G B P		92.89	421	10.22	87	88.15	0.515	3.415	15.08
G B S		93.11	413	9.29	83	83.16	0.535	3.37	15.88
G B Z		94.56	405	10.44	86	91.13	0.54	3.255	16.59
	Mean	94.79	411.16	9.89	87.54	93.25	0.555	3.668	15.12
	Median	95.66	414	9.88	87	93.44	0.585	3.77	15.13
	Range	84.21-97.29	307-482	8.96-11	79-94	83.16-98.07	0.405-0.69	2.98-4.27	13.12-17.88
	SD	2.81	39.82	0.556	4.12	3.84	0.075	0.368	1.11
	CV%	2.96	9.69	5.62	4.71	4.11	13.64	10.04	7.36

** HA- Hatching Percentage, FEC- Fecundity, LW- Larvae Weight, ERR- Effective Rate of Rearing, PR- pupation Rate, SSW- Single Shel weight, SCW- Single cocoon weight, SR- Shell percentage, Y-yellow, G- Green, SD- Standard Deviation, CV- Coefficient of Variation.*

(HA %) was recorded at 94.79 %, indicating a stable reproductive capacity across strains. Fecundity (FEC) showed an average of 411 eggs, while larval weight (LW) averaged 9.89 g, demonstrating consistent larval growth. The pupation rate (PR) was 87.54 %, reflecting good survival rates, whereas single shell weight (SSW) and silk cocoon weight (SCW) averaged 0.555 g and 3.668 g, respectively, indicating the silk yield potential. The mean shell percentage (SR) was found to be 15.12 %, highlighting the efficiency of silk production across strains. The median values for all traits closely align with their respective mean values, indicating a normal distribution of data without extreme outliers. The standard deviation values showed moderate variation in hatchability (2.81), fecundity (39.82), and pupal rate (4.11), whereas higher fluctuations were observed in Single Cocoon weight (0.368) and Shell Percentage (1.11). The coefficient of variation (CV %) was highest for SSW (13.64 %) and SCW (10.04 %), suggesting a greater susceptibility of silk yield traits to seasonal changes compared to reproductive traits. These findings are a trend with previous studies reported by Sharma and Kalita (2017).

3.2 Seasonal effects and Eri silk productivity

To find out the effects of seasonal variations on silk productivity interaction plots were constructed. The interaction plots (Figure 1) illustrate the seasonal variation in different quantitative traits among the Eri silkworm strains. We have divided the results into two parts namely favourable and unfavourable seasons.

3.2.1 Favourable season:

The investigation reveals that early spring (March-April) and spring (April-May) seasons acted as favourable season as the performance of eri silkworm was inclined in these particular seasons in almost all the parameters of all strains but had an extra effect on yellow zebra strain with stable ERR of 90-94 % followed by yellow plain (94%) in summer and performance of both the strains was significantly higher than other the strains in all seasons. Less stability with ERR % ranging form 78-89% was observed in Greenish Blue Plain.

i. **Hatching & Fecundity**: The Highest fecundity was observed, especially in Yellow Zebra and Greenish Blue Zebra strains.
ii. **Larval Weight**: Shows peak weight gain in Yellow Spotted and Greenish Blue Zebra.
iii. **Cocoon Production & ERR %**: Yellow Plain and Yellow Zebra produce the highest number of cocoons, with stable ERR %.
iv. **Pupation Rate**: Pupation rate ranges from 90.12 (GBZ) to highest 98.07 (YZ) exceeding 90 %, indicating optimal rearing conditions.
v. **Shell & Cocoon Weight**: Peaks in April-May, with Yellow Spotted and Yellow Zebra showing maximum cocoon weight.

3.2.2 Unfavourable seasons

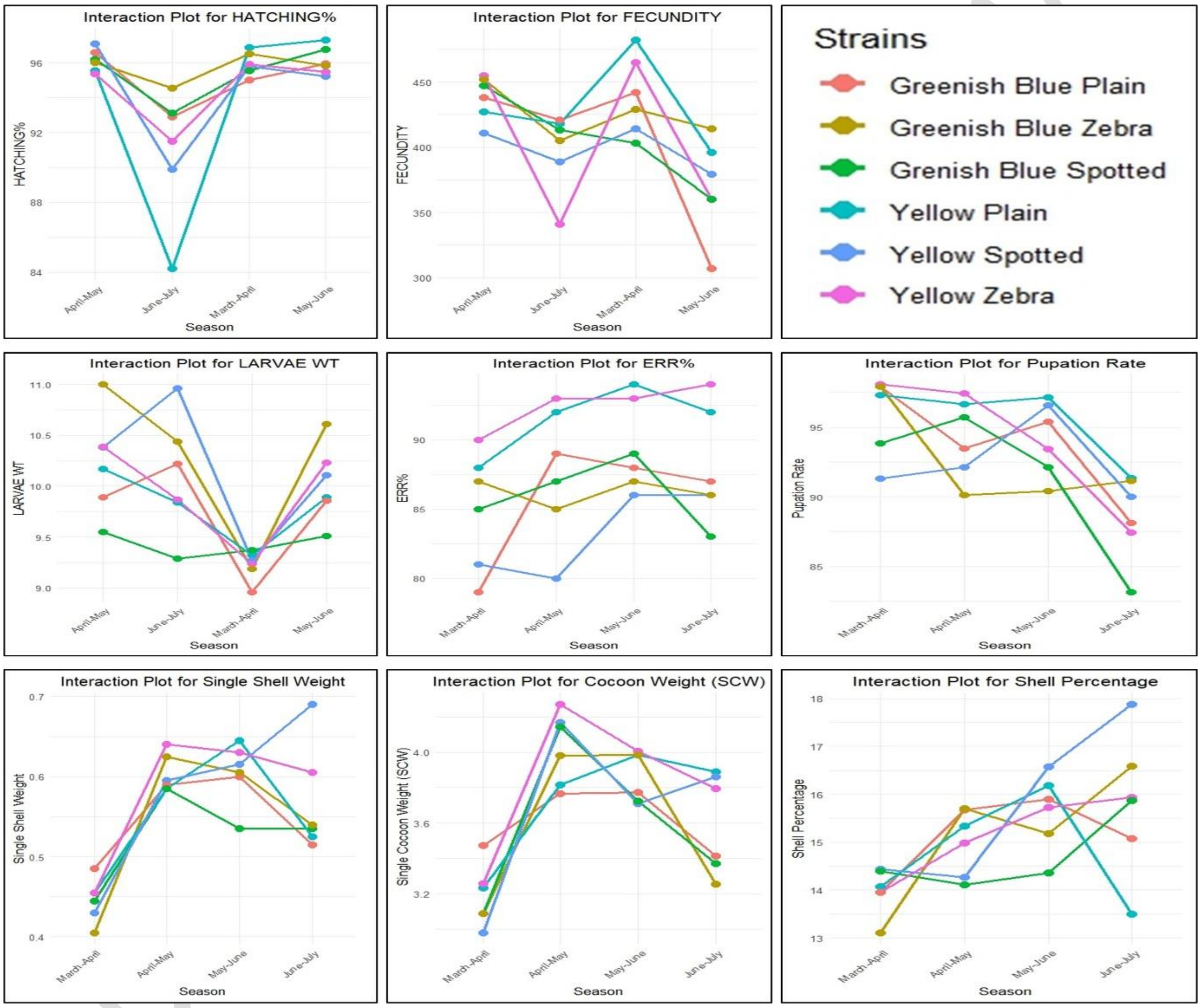
Based on our study, the results indicated that June- July which is the summer season has a negative impact on the rearing performance when compared to the favourable season and hence determined to be unfavourable. The effect was shown in the plot and various parameters of the study

i. **Hatching & Fecundity**: Sharp decline, particularly in Greenish Blue Plain.
ii. **Larval Weight**: Decreases significantly compared to earlier months.
iii. **Cocoon Production & ERR%**: Greenish Blue Plain records the lowest cocoon production.
iv. **Pupation Rate**: Declines steadily, with the lowest values in June-July due to high temperature and humidity stress.
v. **Shell & Cocoon Weight**: Declines from May onwards, with Greenish Blue Zebra showing the lowest weight in June-July.

4. DISCUSSION

Eri silkworm is one of the major agro based economic practices followed by the farmers in eastern and north eastern Indian farmers for their livelihood. It not only gives them economic stability but also serves as food delicious as it is rich in protein. The eri silkworm rearing is conducted throughout the year as it is multivoltine. However, it is important to identify which season will yield the farmer highest profit for commercial exploitation for silk production. The present study is carried out to identify the suitable season and the eri silkworm strain that can be used for higher silk productivity and profits. Six silkworm strains were used in the present study in four seasons (Table 1 and Table 2). The silkworm rearing was conducted using standard practices in all the seasons. Utmost care was taken during rearing in all the seasons. The interaction plots (Figure 1) illustrate the seasonal variation in different quantitative traits among the Eri silkworm strains. The x-axis represents seasons, while the y-axis indicates traits. The different coloured lines represent various strains, showing their response to seasonal changes. The plot shows a sharp decline in hatching percentage during June-July, indicating that this period negatively affects embryonic development. This decline may be attributed to high temperatures and humidity, which adversely influence egg viability and larval emergence (Wankhade *et al*., 2014). The highest hatching rates are observed in March-April and May-June, suggesting these are the most favourable seasons for Eri silkworm rearing. Among the strains, Yellow Plain shows the lowest hatching percentage during June-July, while Greenish Blue Zebra maintains a relatively stable hatching rate, indicating potential genetic resistance to seasonal variations. Similar trends were reported by Siddiqui *et al.,* (2000) who found that summer heat stress affects egg diapause and hatching success in different strains. The plot demonstrates significant seasonal variation in fecundity across different strains. The highest fecundity is observed in March-April, where certain strains, such as Yellow Zebra and Greenish Blue Zebra, exhibit peak reproductive performance. Conversely, May-June and June-July show a sharp decline in fecundity, particularly in the Greenish Blue Plain strain, which records the lowest values. This suggests that high temperatures and fluctuating humidity levels negatively impact oviposition. For the traits of larvae weight the interaction plot displayed unlike fecundity exponential decline recorded in March-April and the highest weight gain observed in strains of Yellow spotted and Greenish Blue Zebra in season of April-May and June-July. Yellow plain and Yellow Zebra produced the highest number of cocoons across all seasons and showed almost similar kind of patterns for an effective rate of rearing (ERR %) and especially in the Greenish Blue Plain strain, which produced the lowest number of cocoons among all strains in the March-April season. This finding suggests that genotype-environment interaction plays a crucial role in ERR (%). Previous studies have also highlighted that optimal temperature (25°C) and humidity (70% RH) significantly enhance cocoon production in silkworms with higher silk gland, larval, shell, and cocoon weight (Rahmathulla and Hiromani, 2013).

Figure 1: Visual display of the interaction between strains and their reared season on different traits

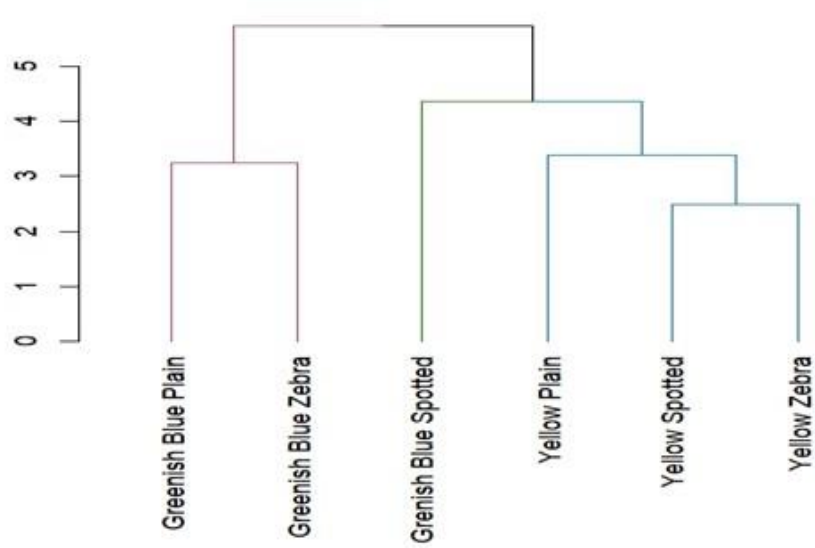


The performance of Eri silkworm strains varied significantly across seasons and the trends observed highlight the influence of environmental factors, particularly temperature and humidity, on silkworm growth and productivity. The interaction plots for SCW, SSW, SR, pupation rate, larval weight and fecundity were highest during April-May and May-June, followed by a sharp decline in June-July. This suggests that the spring season provides optimal conditions (average temperature 25°C and Relative Humidity 75%) and observed minimal variation among all yellow and greenish strains due to less G X E interaction, which promotes cocoon development, larval growth, and moulting efficiency. The decline in performance was observed in June-July (Temp-28°C, RH- 85%) and March-April (Temp-21°C, RH-

60%) due to either an increase or decrease in temperature and relative humidity, which negatively impacted silk gland development, larval survival and successful pupation (Ray, 2010). The results align with findings by Shifa *et al.*, (2014), who reported that high temperatures (>30°C) reduce cocoon weight by affecting larval feeding efficiency and metabolic activity. The Yellow Zebra and Yellow Plain strains consistently showed higher performance in the most favourable season for the traits of fecundity, SSW, SCW, SR, Pupation rate, and ERR % indicating their superior adaptability to those environmental conditions. Greenish Blue Zebra is highly resilient to seasonal variations and provides better and stable performance in fluctuating adverse seasonal conditions for the traits of hatching percentage, Larvae weight and fecundity.

The hierarchical clustering analysis (Figure 2) of Eri silkworm strains was performed using an agglomerative approach, where strains with similar characteristics were grouped together. It reveals distinct groupings based on their economic traits, providing valuable insights for breeding and rearing programs. The dendrogram analysis identified three primary cluster groups where Cluster 1 consists of Greenish Blue Plain and Greenish Blue Zebra which indicate a close phenotypic and genotypic similarity and Cluster II includes Greenish Blue Spotted branches separately but shows a moderate linkage to Cluster I, suggesting some common traits with the greenish-blue strains. Lastly, cluster III which further divided into two sub-clusters. One is sub-cluster IIIA where Yellow Spotted and Yellow Zebra exhibit more similarities in performance traits and another is sub-cluster IIIB which consists of Yellow Plain and indicates significant differences from other yellow strains (Shifa *et al.,* 2014). Cluster III consists of all yellowish strains. The clustering pattern aligns with earlier studies that suggest Eri silkworm strains exhibit a trade-off between reproductive efficiency and silk yield (Swathiga *et al.,* 2019). The separation of Greenish Blue spotted from the Greenish Blue Plain and Greenish Blue Zebra cluster further indicates potential genetic variation within the greenish coloured strains, which could be explored in future breeding programs (Lalitha *et al.,* 2023).

Figure 2: Hierarchical clustering of six different silkworm strains



5.CONCLUSION

The present investigation began with an aim to identify the effects of seasonal variation on Eri silkworm strains. Early spring and spring (March-April and April-May) emerged as the most favourable periods, enhancing fecundity, larval weight, cocoon production, and silk yield. Among the strains, Yellow Zebra demonstrated superior adaptability across all four seasons, making it a potential candidate for high and sustainable silk production. As temperatures rose in June-July, performance declined, particularly in Greenish Blue strains, highlighting the impact of environmental stress on silkworm strains. The clustering analysis further revealed genetic diversity, emphasizing the need for targeted breeding programs. Effective environmental management during stressful periods can help maintain productivity and quality. These findings provide a valuable foundation for optimizing Eri silkworm rearing and improving commercial silk production. In conclusion, this research contributes to enhancing silk yield, benefiting sericulture farmers and promoting sustainable silk farming practices.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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