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Impact of Seasonal Variations on Economic Grainage Traits of Muga Silkworm (*Antheraea assamensis*) in Garo Hills, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Muga silkworm (*Antheraea assamensis* Helfer) is one of the most important silkworms in the sericulture industry and muga silk having high economic demand in the market. Muga silkworm belongs to the order Lepidoptera and family Saturniidae. Being polyphagous and multivoltine, it produces 5 to 6 generation per year and categorised into pre-seed, seed and commercial crop. The pre-seed and seed crops of Muga usually fall in adverse climatic seasons of extreme summer and winter and the productivity sometimes slashes down to 10- 20%.. This study aimed to evaluate the impact of seasonal variations on the grainage traits of Muga silkworms in Garo Hills. The findings revealed that the Baisakhi and Late Bhodia seasons recorded a significantly high coupling, DFL:DFL, Fecundity and Hatching percentage as compared with Aherua and Aghenua season. High temperature, high rainfall, heavy disease and pest infestation during Aherua season and longer duration, low temperature, high fungal infestation and dry climate during Aghenua season reduced the overall yield of muga silkworm.

Keywords: Muga; grainage performance; lepidoptera; commercial crop.

1. INTRODUCTION

"Muga silkworm, *Antheraea assamensis* Helfer, a semi domesticated species belonging to *saturniidae* family is indigenous to north–eastern region of India *viz*., Assam and its neighbouring states of Meghalaya, Arunachal Pradesh, Nagaland, and Mizoram" (Borpuzari et al*.,* 2020). "Assam is the only state which is engaged in the production of reeling cocoons, while the other states have the privilege of producing major quantity of seed cocoons for commercial multiplication" (Mahashankar et al., 2020). "Muga silk is not only famous for its unique golden colour but is also considered as the pride of Assam. The elegant aesthetic appeal of the natural silk is probably unparalleled in the history of textiles. Most of the species of *Antheraea* are polyphagous and it is one of the largest genera in the *saturniidae* family where most species produce valuable silk, which has not yet been domesticated for commercial exploitation" (Kumar et al., 2022).

"Muga silkworm (*Antheraea assamensis* Helfer) is multivoltine, *i.e.* 5-6 times rearing of the silkworm can be done in a year. Muga silkworms are reared during the autumn and spring seasons which are termed as 'Kotia' and 'Jethua' crops, respectively. The cocoons produced during these two seasons are used for producing yarn commercially and hence, these two crops are called commercial crops. 'Kotia' commercial crop rearing is preceded by one crop rearing during June-July which is called 'Aherua' pre-seed crop and subsequent rearing during August-September is called 'Bhodia' seed crop. Similarly, 'Jethua' commercial crop rearing is preceded by 'Jarua' (December-January) pre-seed crop rearing followed by 'Chatua' seed crop rearing. The pre-seed and seed crops of Muga usually fall in adverse climatic seasons of extreme summer and winter and the productivity sometimes slashes down to 10- 20%" (Kumar et al. 2024).

"The key factor of sericulture industry is seed and availability of good quality silkworm seed is vital for viable sericulture industry. Good quality of seed refers to richness of egg laying, viability, uniform hatching and subsequently good rearing performance of the progeny" (Singh et al. 2022). "The change of climatic factors especially relative humidity and temperature is known to affect all the stages of a silkworm's lifecycle including their development and survival. Through several researches it has been found that the optimum temperature for muga silkworm rearing is 20-31 °C and 65 to 95% of relative humidity" (Tikader et al., 2013). Since production and supply of quality seed in desired quantity is one of the challenging tasks of muga industry, a methodological and systematic approach of muga seed production is a need of the hour to overcome the problem of quality seed production in time. Since, grainage season plays the major role for successful cocoon production, it is, therefore, important to evaluate the best season out of the Baisakhi, Aherua, Late Bhodia and Aghenua so as to propagate the best one for commercial utilization. Keeping all these in view this experiment has been conducted to find out the effect of season on grainage parameters of muga silkworm.

2. MATERIALS AND METHODS

2.1 Locale of the Study

The study of seasonal effects on grainage parameters were carried out at the Central Silk

Board, MESSO, P-3 Unit, Rompara, North Garo Hills District, Meghalaya with Longitude 90.34^0 E, Latitude 25.50^0 N and 300 above mean sea level from 2023 to 2024. The general method of grainage of muga silkworm was followed as recommended by Central Silk Board, Muga Eri Silkworm Seed Organization, Guwahati, Assam. Data was collected over two years through grainage performance assessments. The grainage was conducted in four crops/ seasons *i.e.* Baisakhi, Aherua, Late Bhodia and Aghenua. Observations were made on different graiange performance of muga silkworm *i.e*., Pupal period, Valid moth, Natural coupling, Mechanical coupling, DFL: DFL, Seed cocoon: DFL, fecundity and Hatching percentage as per MESSO norms.

2.2 Graiange Parameters Studied

Pupal period (Days): A period of transformation where the larva, encased in a silk cocoon, undergoes metamorphosis into a moth.

Natural coupling (%): For the current study it was calculated by using the formula as given below:

$$\text{Natural coupling (\%)} = \frac{\text{Natural Coupling}}{\text{Natural + Mechanical coupling}} \text{x } 100$$

Mechanical coupling (%): For the current study it was calculated by using the formula as given below:

$$Mechanical\ coupling\ (\%) = \frac{Mechanical\ coupling}{Natural + Mechanical\ coupling} x\ 100$$

DFL: DFL Ratio: The ratio of DFLs obtained from rearing of 1 DFL.

Seed Cocoons: DFL: The cocoon: dfl ratio was calculated by finding the ratio of number of seed cocoon processed to the number of dfls harvested.

Fecundity (Nos.): fecundity refers to the number of eggs laid by a female moth after mating.

Hatching Percentage (%): For the current study it was calculated by using the formula as given below:

$$\text{Hatching (\%)} = \frac{\text{Number of eggs hatched}}{\text{Total number of eggs}} \text{x } 100$$

2.3 Statistical Analysis

The two years data on various parameters regarding grainage performance from 2023 to 2024 and subjected to statistical validation for analysis of variance (ANOVA) on SPSS software.

2.4 Agro-climatic Conditions

The experimental site falls under sub-tropical to sub-humid agro-climatic region with adequate rainfall. The average annual rainfall of the region is about 2400 mm. The weather conditions prevailed from 2023 to 2024 were recorded at Meteorological Observatory and displayed in Fig 1. The rainfall received during the

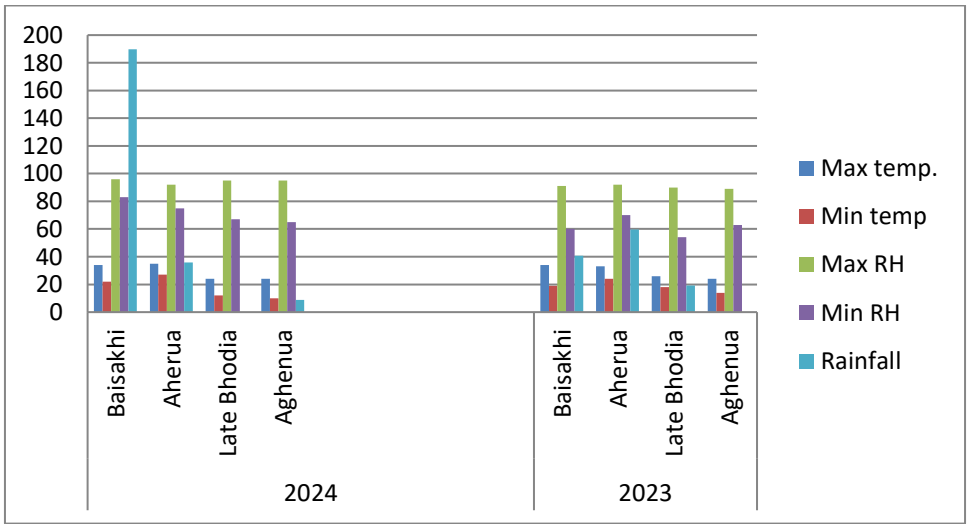

Fig. 1. Meteorological observations

Baisakhi grainage was 40.6 mm, Aherua grainage was 59.7 mm and in Late Bhodia 19.2 mm in the first year of experimentation (2023). During the second year (2024), 189.8 mm in Baisakhi, 35.8mm in Aherua and 8.8 mm rainfall was received in Aghenua crop. The maximum and minimum temperatures in the Baisakhi crop were 19-34^{0}C in 2023 and 22-34^{0}C in 2024, while Aherua crop recorded 24-33^{0}C in 2023, 27-35^{0}C in 2024. 18-26^{0}C in 2023 and 12-24^{0}C was recorded in the Late Bhodia grainage and 14-24^{0}C in 2023 and 10-24^{0}C recorded during Aghenua grainage of 2024. The maximum and minimum RH in the Baisakhi crop were 60-91% in 2023 and 83-96% in 2024, while Aherua crop recorded 70-92% in 2023 and 75-92% in 2024, Late Bhodia and Aghenua grainage recorded 54-90% and 63-89% in 2023 while 67-95% and 65-95% in 2024, respectively.

3. RESULTS AND DISCUSSION

The study reveals that there are considerable variations in grainage performance when the muga silkworm reared in different seasons/ crops. The growth and development of muga silkworm in all the crops are not equal. The growth and development of muga silkworm grainage in all the seasons are recorded as below.

A perusal of the data of Table 1 that the pupal period is directly correlated with the surrounding environmental conditions specially temperature and relative humidity prevailing during the grainage. The pupal duration was recorded 44±3.52 and 45±4.52days in Aghenua in the year of 2023 and 2024, respectively. Baisakhi, Aherua and Late Bhodia crops recorded lesser pupal duration in both the year of experimentation. Similar study made by Kakati (2012) and found that the pupal period complete within 20-25 days in summer and 45-55 days in winter. Valid moth and natural coupling is also directly correlated with surrounding atmosphere and inherent quality. Baisakhi and Late Bhodia crops recorded good number of valid moth i.e. 91.76±9.18 and 97.85±8.81 in the year of 2023 and 93.29±6.46 and 93.92±6.57 in 2024. The same trend also observed in natural coupling where 1st year of experimentation Baisakhi and Late Bhodia recorded 90.45±7.24 and 91.37±9.14, respectively. While in the 2nd year of experimentation 91.02±8.19% natural coupling found the Baisakhi crop and 83.54±6.68% recorded in Late Bhodia crop.

Table 1. Pupal period, valid moth, natural coupling and mechanical coupling of muga silkworm (*antheraea assamensis)* during different grainage seasons

Year	Grainage Season	Pupal Period	Valid Moth %	Natural Coupling %	Mechanical Coupling %
2024	Baisakhi	20±1.80	93.29±6.46	91.02±8.19	8.97±0.72
	Aherua	18±1.44	92.29±8.30	76.12±6.85	23.37±2.22
	Late Bhodia	25±1.75	93.92±6.57	83.54±6.68	16.45±1.48
	Aghenua	45±4.52	89.92±7.19	78.35±5.49	21.61±1.92
2023	Baisakhi	25±2.25	91.76±9.18	90.45±7.24	7.78±0.63
	Aherua	20±1.60	90.78±7.26	80.22±7.21	19.77±1.76
	Late Bhodia	20±1.84	97.85±8.81	91.37±9.14	8.62±0.81
	Aghenua	44±3.52	87.54±7.88	84.06±5.88	15.93±1.24

± *Standard Deviation*

Table 2. DFL:DFL, Seed cocoon: DFL, fecundity and hatching of muga silkworm (*antheraea assamensis)* during different grainage seasons

Year	Grainage Season	DFL: DFL	Seed Coccons:DFL	Fecundity	Hatching %
2024	Baisakhi	1:16.45	2.92:1	162±13.77	85±7.56
	Aherua	1:8.35	3.33:1	140±9.80	70±5.67
	Late Bhodia	1:9.97	3.37:1	175±15.05	90±8.73
	Aghenua	1:7.70	3.33:1	155±15.19	80±6.72
2023	Baisakhi	1:8.85	2.35:1	162±13.45	80±7.76
	Aherua	1:4.60	3.11:1	143±11.29	75±6.67
	Late Bhodia	1:5.52	3.31:1	167±15.69	83±6.58
	Aghenua	1:1.06	2.96:1	160±13.92	75±6.30

± *Standard Deviation*

"Fluctuation of temperature and humidity has significant influence on grainage characters, such as irregular emergence of moth, occurrence of cripple moth and unhealthy moths" (Elumalai et al., 2021) and Hussain et al. (2011) demonstrated that "fluctuations in rearing temperature and humidity adversely affects the egg production and egg fertility in silkworm moths". Mechanical coupling was recorded higher in Aherua grainage as compared to the rest of the season. Majumdar et al., (2020) also conducted "the similar kind of study on grainage performance of muga silkworm for Aherua season reported highest number of mechanical coupling".

The highest DFL per DFL was recorded during Baisakhi *i.e.* 1:8.85 and 1:16.45 in the year of 2023 and 2024, respectively followed by Late Bhodia seasons. The lowest DFL yield was recorded during Aghenua in both the year of experimentation. Similar study conducted by Lalitha et al., 2023 and found that "the highest seed cocoon yield per dfl in eri silkworm was recorded during autumn followed by winter/ spring and late monsoon seasons. The lowest seed cocoon yield was recorded during early monsoon and summer.The critical factors that reduced the DFL per DFL during Aherua and Aghenua were low hatching percentage, mortality due to uzi infestation, diseases and impact of high and low temperature during spinning".

The maximum fecundity and hatching percentage has been obtained from the cocoons reared in Late Bhodia crop. The Late Bhodia and Baisakhi were at par with each other in both the year of experimentation. Subharani and Jaiprakash (2015), revealed that "max. temperature, min. temperature and max. relative humidity showed negative association with abiotic factors and positive association with min relative humidity (significant with max. temperature and humidity). Rise in temperature and humidity affects the mating behaviour in moths, which may cause a lesser transfer of sperms resulting in increase of unfertilized eggs. It also leads to embryonic mortality, resulting in damage of the embryo, thus affecting the hatching". Chanotra et al., (2024) also recorded hatching percentage in different seasons ranging from 62.85% with an average of 76.93%.

4. CONCLUSION

India is a sub-tropical country and environmental conditions are the limiting factors of muga silkworm rearing. Majority of muga grainuers encounters the various environmental problems and lose their crops or produce inferior quality of cocoon and silk. Based on the experiments, Baisakhi and Late Bhodia crops recorded higher fecundity, DFL:DFL and hatching percentage as compare with Aherua and Aghenua crops, due to optimum temperature and relative humidity and less fluctuations of temperature. High incidence of bacterial, viral and fungal diseases was also observed in Aherua and Aghenua crops late age rearing due to high temperature fluctuations.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

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 writing or editing of this manuscript.

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COMPETING INTERESTS

We have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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