AN ABSTRACT OF THE THESIS SUBMITTED TO NAGALAND UNIVERSITY IN PARTIAL FULFILMENT FOR THE AWARD OF DEGREE OF DOCTOR OF PHILOSOPHY IN ZOOLOGY

Title of the thesis

ALTITUDINAL EFFECT AND HOST PLANT PREFERENCE ON GROWTH AND PRODUCTION OF ANThERAEa ASSAMA WESTWOOD

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CHAPTER I: Introduction

India has the distinction of being the only country in the world, producing all the five commercially exploited silk varieties viz. Mulberry, Tropical Tasar, Temperate/Oak Tasar, Eri and Muga of which the golden yellow muga silk of Assam is unique product of India and nowhere in the world is available. Muga culture is a continuous chain of several production activities starting from egg production to rearing of *Antheraea assama* West wood (= *Antheraea assamensis* Helfer) in the raised flora by rearers for production of cocoons. Muga silk worm fed with leaves of *Persea bombycina* Kost and *Litsea polyantha* (the two primary host plants) produces golden yellow cocoons, however when reared on *Litsea citrata* Blume, the secondary host plant produces creamy white cocoons.

Sustainability of muga silk industry has been facing serious threat in recent years due to global warming and various anthropogenic reasons. The traditional commercial muga growers of Assam generally visit foot hills as well as higher altitudinal areas of neighbouring hill states to collect wild, healthy seed cocoon for conducting commercial crop which emphasize that altitudinal effect, climatic variation and host plant preference play a great role in muga cocoon production. In this context, rearing schedule and technology of muga crops has to be standardized to suitably adjust the local conditions particularly in high altitude so that the crucial gap between production of seed cocoons and their requirement for each commercial crop is minimized. Hence a systematic study of rearing has been undertaken on three host plants (*Persea bombycina*, *Litsea polyantha* and *Litsea citrata*) in two locations at
North Lakhimpur, Assam (low altitude) and Mokokchung, Nagaland (High altitude) for two consecutive years to have comparative analysis of altitudinal effect and host plant preference on growth and production of *A. assama*.

**CHAPTER II: Description of study sites, climate and host plants**

The experimental sites selected for present study was located in Ungma of Mokokchung (Mokokchung district) in Nagaland at higher altitude (1325m amsl) and Japisajia of North Lakhimpur (Lakhimpur district) in Assam at lower altitude 135m amsl). Rearing of *A. assama* was conducted simultaneously in three different seasons i.e. spring (April-June), summer (July-September) and autumn (October-December) on three host plants namely *P. bombycina* (Som), *L. polyantha* (Soalu) and *L. citrata* (Mejankari). *P. bombycina* was common to both places, whereas *L. polyantha*, the another primary host plant was utilized in lower altitude and *L. citrata*, the important secondary host plant which grows abundantly in Nagaland was used in higher altitude.

The four distinct seasons prevailing in Nagaland are cold (winter), hot (pre-monsoon), rainy (monsoon) and cool dry season (retreating monsoon) and the hilly terrain with about 52% forest cover is instrumental in shaping the cool and pleasant climatic conditions. Mokokchung district, covering an area of 1615 Km² lies at 26°17'-26°39' N latitude and 94°18'-94°37' E longitude. Assam within the rain shadow zone lies at 26°30' - 29°30' N latitude and 91°30' - 97°30' E longitude. Persistent high humidity and moderate temperature throughout the year, extensive water bodies, local depressions, elevations and extensive forests play important role
for shaping veritable climatic conditions of Assam. Climate wise the year in Assam can be divided broadly into the wet (March to September) and cool dry season (October to February) period. Lakhimpur district is located in north-east corner of Assam at 26°48’-27°53’ N latitude and 93°42’-94°20’E longitude covering 2953 Km².

While variation in mean maximum temperature was not much evident, mean minimum temperature was considerably variable during different rearing seasons between Mokokchung and North Lakhimpur. The range of maximum and minimum temperature in all seasons was higher in Mokokchung than North Lakhimpur indicating colder climatic regime on the former. Persistent high humidity in North Lakhimpur than Mokokchung was mostly influenced by high rainfall and moderately high temperature throughout the year. Both locations in lower and higher altitude represent an ideal sub-tropical climate, however, Lakhimpur district of Assam exhibited certain self regulating mechanisms of occasional winter rain and summer drought while Mokokchung district witnessed prolong winter. The mean annual rainfall for last 20 years in Mokokchung was lower than North Lakhimpur

*P. bombycina* (Som) and *L. polyantha* (Soalu) are the primary food plant of muga silk worm and are used for production of commercial and seed cocoons in upper and lower Assam. Sixteen ecotypes of Som and ten ecotypes of Soalu are described. The cocoons produced in Som and Soalu are golden brown in colour. *L. citrata* (Mejankari) is the most important secondary host plant whose distribution in plains of Assam is very sparse but grown naturally in Mokokchung, wokha and
Tuensang district of Nagaland. Muga silk worm fed on *L. citrata* produces a kind of silk known as Mejankari silk which is admired for its durability, luster and creamy white shade.

**CHAPTER III: Physico-chemical characteristics of soil and host plants**

Analysis of physico-chemical characteristics of soil viz. moisture content (%), soil pH, organic carbon (%), total nitrogen (kg/ha), available phosphorus (kg/ha) and available potassium (kg/ha) in different seasons between North Lakhimpur and Mokokchung revealed that the soil quality in both sites were suitable for growth of muga silkworm food plants with balanced amount of these nutrients. Total nitrogen and phosphorus decreased with the increase in altitude, while organic carbon and potassium exhibited an opposite trend which might be due to various factors such as temperature, rainfall, altitudinal effect, vegetation cover, land use etc.

In North Lakhimpur, Assam (low altitude), highly significant variation in nutrient content among different leaf types of two primary food plants i.e. Som and Soalu was observed exhibiting a trend of tender > medium > mature in moisture, nitrogen, crude protein content, while the reverse trend i.e. mature>medium>tender was seen in crude fibre, carbohydrate and total ash. However no definite trend was seen in soluble and reducing sugar in both host plants. In Som, all the foliar contents were found to be maximum during summer followed by autumn and spring season, however in Soalu, different trend was observed i.e. spring>autumn>summer in case of nitrogen, crude protein, crude fibre, carbohydrate, reducing sugar;
summer>autumn>spring in moisture; autumn>spring>summer in soluble sugar and
autumn>summer>spring in total ash. The annual mean of all foliar constituents were
found to be higher in Som than Soalu. The results suggested both individual and
combined effect of leaf types, seasons and host plants on the nutritive value of leaves
which greatly influenced the silk worm feeding from initial to maturation stage to
produce healthier cocoons in different rearing seasons.

In Mokokchung, Nagaland (high altitude) seasonal variation of foliar
constituents viz. moisture content, nitrogen, crude protein, crude fibre, carbohydrate,
soluble and reducing sugar and total ash in different leaf types of primary (Persea
bombycina) and secondary (Litsea citrata) food plants were found to be highly
significant. Moisture content was recorded to be minimum during spring and autumn
season in Som than Mejankari, however the trend was found to be reverse in case of
nitrogen, crude protein and crude fibre which were found to be less during summer in
Som than Mejankari. Further percentage of carbohydrate, soluble sugar, reducing
sugar and total ash were recorded to be maximum in all seasons in Som than
Mejankari. While nitrogen, crude protein, crude fibre, carbohydrate, soluble sugar
and total ash were higher in som during autumn, Mejankari retained higher
percentage of these constituents during summer season except for carbohydrate which
was maximum in spring season. The annual mean of all foliar constituents were found
to be higher in Som than Mejankari except for moisture content The comparative
studies on seasonal variations between leaf types of both P.bombycina and L.citrata
revealed significant differences for moisture, total carbohydrate, soluble sugar, total
nitrogen and crude protein whereas difference were insignificant for reducing sugar, crude fibre and total ash. The results suggested both individual and combined effect of leaf types, seasons and host plants on the nutritive value of leaves which greatly influenced the silk worm feeding on different larval stages and highlighted the importance of Mejankari at par with Som and Soalu host plant on rearing performance and cocoon production in different season.

Foliar constituents of *Persea bombycina* in both locations of lower and higher altitude, showed a declining trend in the moisture, nitrogen, and protein content from tender to mature leaves, however the reverse trend i.e. mature>medium>tender was found in respect of crude fibre, carbohydrate, reducing sugar and total ash in all seasons except for slightly higher amount of soluble sugar content in medium leaves highlighting significant altitudinal influence on the chemical composition in different maturity of leaves. Mean seasonal and annual value of moisture, nitrogen, protein and crude fibre was more in lower altitude (North Lakhimpur) and carbohydrate, soluble and reducing sugar and total ash was more in higher altitude (Mokokchung). On average, foliage in higher altitude exhibited comparatively higher values for carbohydrate, soluble sugar, reducing sugar and total ash whereas, the foliages of lower altitude revealed higher value for moisture, total nitrogen, crude protein and crude fibre content. Based on the present findings, it could be suggested that *Persea bombycina* located in higher altitude i.e. Mokokchung, the non traditional zone was nutritionally at par with the traditional zone of located in Lower altitude i.e. North Lakhimpur and suitable for muga silkworm rearing.
CHAPTER IV: Morphometric variation of *Antheraea assama* Westwood

Muga silkworm rearing in North Lakhimpur, Assam was conducted on *Persea bombycina* (Som) and *Litsea polyantha* (Soalu) in three seasons i.e. spring, summer and autumn only. Seasonal mean length and weight in different larval instars was higher in Soalu than Som. Length, breadth and weight of female cocoons and pupa was higher than its male counterpart in both host plants and respective seasons.

A comparative rearing experiment on Som and Mejankari in a muga producing area of Mokokchung Nagaland showed that seasonal mean of larval length ranged from 0.97±0.09 cm to 1.11±0.08 cm (1st instar) to 7.94±0.88 cm to 9.32±0.27 cm (5th instar) respectively in *L. citrata* and *P. bombycina*. While larval volume was found to be higher in Som than Mejankari, no significant difference was observed in larval weight between the two host plants. The larvae also produced luster and creamy white shaded cocoons.

Rearing of wild population of *Antheraea assama* in three different seasons on two host plants in Mokokchung, Nagaland exhibited strong seasonality and host plant effect on growth and development in different larval stages, cocoon and pupa. Each larval instar exhibited distinguishing colour variation and tubercular arrangement. The volume (length x breadth) and weight of the larva during first instar was comparatively less in Som than Mejankari which was however getting reverse along with developmental stages and attained maximum volume and weight in Mejankari. Cocoons colour varied in host plants and seasons. While cocoon and pupal parameters in Som was found to be better than that of Mejankari, spring season was
more favourable followed by autumn and summer season showing significant interaction effect due to host plant x season. The moths of wild variety which was larger in size and deeper in colour than cultivated variety have wing span of 142-153 mm in male and 153-172 mm in female.

The significant differences in length, breadth and weight in larval stages of *Antheraea assama* from first to fifth instars in different seasons highlighted the effect of altitudinal and climatic variation between Lakhimpur and Mokokchung. Morphometric parameters of female cocoon and pupa were higher than its male counterpart in respective seasons in both sites. The length, breadth and weight of cocoon and pupa was maximum during spring season with a decreasing trend through summer and autumn in lower altitude, however a seasonal fluctuation was observed in higher altitude exhibiting maximum during autumn. The volume and weight of cocoon and pupa during summer and autumn season in Mokokchung was higher than Lakhimpur and exhibited a strong interaction effect due to season, site and sex.

CHAPTER V: Altitudinal effect and host plant preference on rearing performance of *Antheraea assama* Ww.

Rearing of *A. assama* on *P. bombycina* took 21.2±1.37 to 34.0±2.11 days to complete its larval period, while on *L. polyantha* the duration was 20.1±1.34 to 33.0±2.19 days in indifferent seasons. The total mean production parameters viz. fecundity, hatching percentage, ERR and cocoon:dfl in Som and Soalu were 195.67±9.71 and 188±10.00, 82.33±6.43 and 81.00±5.57, 42.73±17.47 and
48.20±17.05, 46.67±20.82 and 45.67±27.68 respectively. Shell ratio, filament length, filament denier and raw silk recovery did not show significant difference between the two host plants.

In Mokokchung, the larval period of cultivated variety of A. assama ranged from 34.9±0.72 to 37.4±0.99 days and 39.7±0.73 to 45.2±1.61 days in P.bombycina and L.citrata respectively in indifferent seasons. The important economic characters viz. fecundity (nos.), hatching percentage, ERR (%) and cocoon:dfl ratio in Litsea citrata ranged from 171.50±9.63 to 198.33±8.64, 60.12±2.66 to 71.25±1.71, 40.77±1.02 to 57.37±1.26 and 53.0±1.89 to 70.0±4.56 respectively in different seasons. The mean dimension (length x breadth) and weight of cocoon, shell ratio, filament length, filament denier and raw silk recovery in L.citrata was comparable and at par with P. bombycina.

Rearing of wild variety of A. assama took 28.2±0.91 to 37.2±1.00 days to complete its larval period on P. bombycina while on L. citrata, the duration was 33.4±0.78 to 45.2±0.94 days in different seasons. The important economic characters viz. fecundity (Nos.), hatching %, effective rate of rearing (%) and cocoon:dfl ratio in L. citrata ranged from 199.10±9.63 to 200.20±8.64, 71.28±2.66 to 76.21±1.71, 28.35±1.02 to 58.87±1.26 and 39.90±1.89 to 87.40±4.56 respectively in different seasons. The golden to pinkish white and tough texture cocoons measured a length of 3.78±0.11 to 4.42±0.12 in male and 4.31±0.14 to 5.04±0.12 in female and a breadth of 1.44±0.04 to 1.56±0.06 in male and 1.64±0.06 to 1.68±0.07 in female when fed on
the leaves of *L. citrata*. Shell ratio (%), filament length (cm), filament denier and raw silk recovery (%) of *L. citrata* fed cocoons are at par with that of *P. bombycina*.

Comparative rearing analysis of both cultivated and wild variety of muga silk worm on Som showed strong seasonality in larval duration having the sequence of summer<spring<autumn season and was correlated with the higher temperature and optimum humidity. While mean values for all production parameters was recorded to be less in cultivated variety than the wild ones, both varieties exhibited seasonal fluctuation of all production parameters with a minimum record during summer. Maximum green cocoon weight for both cultivated and wild variety was recorded in female during autumn and spring season respectively. While total mean of shell weight, silk ratio and raw silk recovery did not show any significant difference, the filament length and denier differed significantly between the two varieties.

Larval duration of cultivated and wild population on Mejankari also exhibited strong seasonality with temperature and humidity having the sequence of summer < spring< autumn season. While total mean fecundity and hatching percentage in wild population was recorded to be higher than cultivated one, the reversed trend was observed in mean effective rate of rearing and cocoons per dfl ratio. Total mean of green cocoon weight was higher in wild than the cultivated one. Shell weight and SR% was recorded to be maximum in female of cultivated population than the wild ones which had been found to be reversed in male cocoons. Filament length (m) and filament denier were found to be maximum in cultivated variety than wild one in all
seasons; however there was apparently no difference in raw silk recovery (%) between the two populations in different seasons.

Total larval duration during summer and spring was significantly shorter in North Lakhimpur than Mokokchung, however no significant difference was observed during autumn season. Seasonal and mean pupal period was recorded to be shorter in North Lakhimpur than Mokokchung. Higher fecundity and hatching percentage in lower altitude and maximum ERR and cocoon production in higher altitude emphasized strong altitudinal effect on production parameters due to climatic variation in both places. Further season to season analysis on rearing and cocoon production between the two places highlighted the fact that rearing performance in higher altitude was comparatively better than lower altitude during summer and autumn season and also showed highly significant difference between locations, seasons and interaction effect due to location x season. Total mean of green cocoon weight (gm) was higher in Mokokchung than North Lakhimpur with the record of maximum weight in female during spring and minimum in male during autumn season in North Lakhimpur. Silk ratio (%) was recorded to be higher in Mokokchung than North Lakhimpur in both sexes in all seasons. While filament length and raw silk recovery was higher in North Lakhimpur than Mokokchung denier was recorded to be higher in Mokokchung than North Lakhimpur.

Rearing of muga silk worm even on same host plant in different seasons and locations resulted in variability among different characters like ERR, cocoon weight,
shell weight, silk filament length and shell ratio and indicated a promising future in terms of producing novel silk with high economic value for the region. While spring and autumn seasons were the best suited for commercial crop production, cocoons produced during summer season could be used for seed purpose in ensuing autumn crop. Further, the diapausning character of *A. assama* indicated its adaptability to severe winter at higher altitudes and would provide enormous opportunities for rearing of wild variety.

The congenial climatic condition in Nagaland state particularly during spring, summer and autumn seasons was highly suitable for muga culture which might have tremendous potentialities to emerge as important subsidiary crop next to agriculture for livelihood. However the knowledge of muga silk production was very poor among farmers due to lack of transfer of technology, which was yet to reach grass root level. In spite of having certain problems like weak research and extension support, inadequate infrastructure, processing and market facilities of seed and commercial cocoons, inadequate package of practice for plantation, rearing and grainage, adjustment to the climatic fluctuation etc., muga culture has high prospect in this state for large scale development due to its great market demand particularly for seed cocoons, availability of vast track of vacant land for plantation, employment opportunity to skilled and unskilled manpower etc. A critical SWOT analysis is made towards upliftment of muga silk industry that requires the complete package from egg production to finished cloth to assist muga farmers, reelers, weavers and traders to generate income from the sale of their respective raw materials. Having seen the
socioeconomic perspective of muga silk industry towards contributing renewal interest among marginal farmers, women and unemployed youths, it is suggested that Mokokchung may be considered as an alternative eco-pocket for rearing of muga silk worm particularly during pre-seed and seed crops which are the most important for any successful commercial crop.

CHAPTER VI: Summary

This chapter summarizes the overall findings in the present study. It gives an account of climatic variation of both study sites and description of host plants with reference physico-chemical characteristic of soil and host plants. Detail comparative study on morphometric variation and rearing performance of *Antheraea assama* (both varieties) on three host plants in low and high altitude highlighted altitudinal effect and host plant preference. A critical SWOT analysis is made to emphasize on socioeconomic perspective of muga silk industry in Nagaland.

The thesis is completed with the exhaustive list of references cited in the main text.

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