CHAPTER VI

SUMMARY
Sustainability of muga silk industry, which is prerogative of North Eastern Region, particularly the Brahmaputra valley of Assam, 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* Ww.

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 *Antheraea assama* Westwood was conducted simultaneously in three different seasons i.e. spring (April-June), summer (July-September) and autumn (October-December) on three host plants namely *Persea*
bombycina Kost (Som), Litsea polyantha Juss (Soalu) and Litsea citrata Blume (Mejankari). *Persea bombycina* (Som) was common to both places, whereas *Litsea polyantha* (Soalu), the another primary host plant was utilized in lower altitude and *Litsea citrata* (Mejankari), the important secondary host plant which grows abundantly in Nagaland was used in higher altitude.

Nagaland is largely a mountainous state rising from the Brahmaputra Valley in Assam to about 2,000 feet (610 m) and rise further to the southeast, as high as 6,000 feet (1,800 m). The hilly terrain of Nagaland with the forest cover of about 52% is instrumental in shaping the cool and pleasant climatic conditions. Nagaland may be divided in to four distinct seasons. The four distinct seasons prevailing in Nagaland are cold (winter), hot (pre-monsoon), rainy (monsoon) and cool dry season (retreating monsoon). Mokokchung district which lies at 26°17'-26°39' N latitude and 94°18'-94°37' E longitude covers an area of 1615 Km² and has an altitude of 1325 m above mean sea level. The location of Assam within the rain shadow zone lies between 26°30' N and 29°30' N latitude and between 91°30' E and 97°30' E longitude at an average altitude of 135 m above mean sea level. 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 at an altitude of 135m amsl.

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 exhibits certain self regulating mechanisms of occasional winter rain and summer drought while Mokokchung district witnesses prolong winter. The mean annual rainfall for last 20 years in Mokokchung was lower than North Lakhimpur

*Persea bombycina* Kost (Som) and *Litsea polyantha* Juss (Soalu) are the primary food plant of muga silk worm mostly 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. *Litsea 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 *Litsea citrata* produces a kind of silk known as Mejankari silk which is admired for its durability, luster and creamy white shade.

Analysis of physico-chemical characteristics of soil in different seasons between North Lakhimpur and Mokokchung (moisture Content % = spring: $15.03 \pm 0.68$ and $27.79 \pm 1.01$, summer: $37.83 \pm 4.02$ and $31.36 \pm 0.78$, autumn: $17.83 \pm 2.32$ and $18.05 \pm 0.58$; soil pH = spring: $5.61 \pm 0.11$ and $5.15 \pm 0.10$, $5.35 \pm 0.06$ and $5.14 \pm 0.14$, autumn: $4.91 \pm 0.09$ and $4.90 \pm 0.09$; organic carbon % = spring season: $1.18 \pm 0.13$ and $1.70 \pm 0.19$, summer: $1.04 \pm 0.09$ and $1.68 \pm 0.14$, autumn: $0.87 \pm 0.02$ and $1.52 \pm 0.05$; total nitrogen kg/ha= spring: $501.76 \pm 76.02$ and $456.55 \pm 49.52$ kg/ha, summer: $522.14 \pm 27.89$ and $515.21 \pm 23.14$ kg/ha, autumn: $397.23 \pm 11.84$ and $399.00 \pm 11.90$ kg/ha; available phosphorus (kg/ha)= spring: $37.61 \pm 0.81$ kg/ha, summer: $25.00 \pm 1.66$ kg/ha, autumn season (31.72 \pm 0.40 kg/ha); available potassium kg/ha=spring: $238.11 \pm 1.84$ and $343.40 \pm 2.66$ kg/ha; summer: $229.55 \pm 5.32$ and $373.50 \pm 8.65$ kg/ha; autumn: $217.61 \pm 8.83$ and $372.50 \pm 15.11$ kg/ha) reveal that the soil quality in both sites are 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 aspect, 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. *Persea bombycina* (Som) and *Litsea polyantha* (Soalu) have been 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 season followed by autumn and spring, 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 (percentage) of all foliar constituents were found to be higher in Som than Soalu i.e. moisture (68.89± 0.74 and 64.84± 1.29), nitrogen (3.63± 0.43 and 3.10± 0.87), crude protein (22.65± 0.57 and 19.24± 0.66), crude fibre (13.95± 0.85 and 11.87± 1.21), carbohydrate (11.78± 0.84 and 9.01± 0.67), soluble sugar (4.36± 0.66 and 4.09± 0.66), reducing sugar (2.35± 0.77 and 2.12± 0.31) and total ash (4.33± 0.54 and 4.13± 0.65) respectively. The results suggest both individual and combined effect of leaf types, seasons and host plants on the nutritive value of leaves which greatly influences 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 be minimum during spring and autumn season in Som than Mejankari, however the trend is found to be reverse in case of nitrogen, crude protein and crude fibre which are found to be less during summer in Som than Mejankari. Further percentage of carbohydrate, soluble sugar, reducing sugar and total ash are 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 is maximum in spring season. The annual mean (percentage) of all foliar constituents were found to be higher in Som than Mejankari except for moisture content i.e. moisture (60.47± 0.49 and 64.45± 0.91), nitrogen (2.82± 0.11 and 2.73± 0.07), crude protein (17.63± 0.71 and 17.10± 0.44), crude fibre (7.05± 0.83 and 6.98± 1.01), carbohydrate (17.36± 0.24 and 12.61± 0.42), soluble sugar (4.50± 0.13 and 2.08± 0.28), reducing sugar (2.39± 0.06 and 0.72± 0.03) and total ash (7.17± 0.11 and 4.97± 0.07) respectively. The comparative studies on seasonal variations between leaf type of both *P.bombycina* (Som) and *L.citrata* (Mejankari) 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 suggest both individual and combined effect of leaf types, seasons and host plants on the nutritive value of leaves which greatly influences the silk worm feeding on different larval stages and highlight 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 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) in respective seasons except for slight decrease of soluble and reducing sugar during summer season. The mean annual moisture content, nitrogen, crude protein and crude fibre in North Lakhimpur (68.89±0.74, 3.63±0.43, 22.65±0.57 and 13.95±0.85 respectively) was recorded to be higher than Mokokchung (60.47±14.65, 2.82±0.11, 17.63±0.71 and 7.05±0.83 respectively); however a reverse trend having higher amount in Mokokchung than North Lakhimpur has been observed in case of carbohydrate
(17.36± 0.24 and 11.78± 0.84), soluble sugar (4.50± 0.13 and 4.36± 0.66) reducing sugar (2.39± 0.06 and 2.35± 0.77) and (7.17± 0.11 and 4.33± 0.54) respectively. 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 is suggested that Persea bombycina located in higher altitude i.e. Mokokchung, the non traditional zone is nutritionally at par with the traditional zone of located in Lower altitude i.e. North Lakhimpur and suitable for muga silkworm rearing.

Although North Lakhimpur, Assam, the low altitudinal area is a traditional zone for muga culture, the present rearing and grainage of muga silk worm was conducted on Persea bombycina and Litsea polyantha in three seasons i.e. spring, summer and autumn only. Seasonal mean of larval length ranges from 1.12±0.12 to 1.22±0.08 cm (1st instar) to 9.53±0.26 to 10.25±0.06 cm (5th instar) in P. bombicina and L. polyantha respectively. The weight of in 5th instar larval was higher in Soalu (7.59±0.15 gm) than Som (6.88±0.83 gm). Length breadth and weight of female cocoons and pupa was higher than its male counterpart in both host plants and respective seasons. Further total mean cocoon and pupal parameters in Soalu was found to be better that that of Som. It takes 24.1±1.62 to 34.0±2.11 days to complete its larval period on P. bombycina, while on L. polyantha the duration is 23.0±1.54 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 are 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 (8.04±1.55 and 7.46±1.33%), filament length (411.10±10.95 and 383.38± 9.97 m), filament denier (5.17 and 5.55) and raw silk recovery (48.08% and 44.67%) as recorded in *P. bombycina* and *Litsea polyantha* respectively did not show significant difference.

Muga silkworm rearing is comparatively new to Nagaland and generally conducted only on Som plants. The larvae also produce luster and creamy white shaded silk known as Mejankari silk while feeding on *Litsea citrata* Blume (Mejankari) the secondary host plants grown naturally in Mokokchung, Nagaland. A comparative rearing experiment on Som and Mejankari in a muga producing area of Mokokchung showed that seasonal mean of larval length ranges 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 is found to be higher in Som than Mejankari, no significant different has been observed in larval weight between the two host plants. It takes 34.9±0.72 to 37.4±0.99 days to complete its larval period on *P. bombycina* while on *L. citrata* the duration is 39.7±0.73 to 45.2±1.61 days in indifferent seasons. The important economic characters viz. fecundity (nos.), hatching percentage, ERR (%) and cocoon:dfl ratio in *Litsea citrata* ranges 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 of creamy white cocoon in *L. citrata*
ranges from 6.50±0.48 to 8.10±0.56 with an average weight ranging from 4.61±0.38 to 5.24±0.76 in different seasons which are comparable with that of *P. Bombycina*. Shell ratio (8.26±1.057 % and 10.33±1.184%), filament length (329.09± 9.97 cm and 373.33±10.95 cm), filament denier (4.8 and 5.8) and raw silk recovery (42.6% and 43.58%) in *L. citrata* and *P. bombycina* respectively are at par with each other and the rearing potentiality is also quite encouraging on *L. citrata* which produces much stronger, thicker, glossy and durable cocoons. Thus it is highly essential to conserve natural plantation of *Litsea citrata* as well as to take up Mejankari silk farming along with Som in higher altitude to boost Mejankari silk production which can create a new horizon for the muga silk industry.

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 seasonal mean of larval length ranges from 0.94±0.07 - 1.07± 0.10 cm (1st instar) to 9.77±0.28 - 8.45±0.4 cm (5th instar) respectively in *Persea bombycina* and *Litsea citrata*. 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 of 14.99 cm³ and 11.56 gm in Som and 11.35 cm³ and 10.74 gm in Mejankari respectively. Cocoons colour
varied in host plants and seasons. Length breadth and weight of female cocoons and pupa was higher than its male counterpart in both host plants and respective seasons. While cocoon and pupal parameters in Som was found to be better that that of Mejankari, spring season was more favourable followed by autumn and summer season showing significant interaction effect due to host plants x seasons. The moths of wild variety which is larger in size and deeper in colour than cultivated variety have wing span of 142- 153 mm in male and 153 -172mm in female. It takes 28.2±0.91 to 37.2±1.00 days to complete its larval period on P. bombycina while on L. citrata, the duration is 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 range 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 measure 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 have shown strong seasonality in larval duration having the
sequence of summer < spring < autumn season with 28.2 ± 0.65 to 25.5 ± 0.91, 34.9 ± 0.72 to 32.5 ± 1.04 and 37.4 ± 0.99 to 37.5 ± 1.0 days respectively and was correlated with the higher temperature and optimum humidity. While mean values for all production parameters have been 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 (gm) for both cultivated and wild variety was recorded in female during autumn (6.19 ± 0.37) and spring (8.27 ± 0.17) season respectively. While total mean of shell weight, silk ratio and raw silk recovery did not show any significant difference, the filament length (373.33 ± 10.95 and 309.28 ± 22.47 m) and denier (5.8 and 4.7) respectively between cultivated and wild variety differed significantly.

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 with 39.7 ± 0.73 to 37.5 ± 1.43, 33.4 ± 0.66 to 30.5 ± 0.78 and 45.2 ± 1.61 to 42.5 ± 0.94 days respectively. Total mean fecundity in wild population (199.60 ± 0.56) was recorded to be higher than cultivated one (186.13 ± 13.57). Average hatching percentage was found to be higher in wild (74.00 ± 2.49) than cultivated (66.97 ± 6.01) variety having shown no definite seasonal trend in both populations. Mean effective rate of rearing (ERR) and cocoons per dfl was recorded higher in cultivated (47.87 ± 8.57 and 59.00 ± 9.539) than wild population (39.10 ± 17.082 and 57.57 ± 25.982) except for spring season in
wild variety showing higher value than cultivated ones. Total mean of green cocoon weight (gm) was higher in wild (5.76±0.88) than the cultivated one (5.47±0.17), with the record of maximum weight in female-wild (8.27±0.18) and minimum in male-cultivated (4.85±0.15) during spring season. 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.

Rearing conducted on *Persea bombycina* Kost in two locations i.e. North Lakhimpur, Assam (low altitude-high temperature) and Mokokchung, Nagaland (high altitude-low temperature) simultaneously for three seasons has shown significant effect of altitudinal and climatic variation on morphometric characteristics during different development stages of muga silk worm. The significant differences in length, breadth and weight in larval stages from first to fifth instars in different seasons highlighted the effect of climatic variation between Lakhimpur and Mokokchung. While difference in length of 5th stage worms is not significant, the mean difference on breadth and weight is highly significant between the two sites. Morphometric parameters of female cocoon and pupa are higher than its male counterpart in respective seasons in both sites. The length, breadth and weight of cocoon and pupa is maximum during spring season with a decreasing trend through summer and autumn in lower altitude, however a
seasonal fluctuation is observed in higher altitude exhibiting maximum during autumn. The volume and weight of cocoon and pupa during summer and autumn season in Mokokchung is higher than Lakhimpur and exhibits a strong interaction effect due to seasons, sites and sex. Total larval duration during summer and spring was significantly shorter in North Lakhimpur (21.2±1.37 and 24.1±1.62 days respectively) than Mokokchung (28.2±0.65 and 34.9±0.72 days respectively), however no significant difference was observed between lower (34.0±2.11) and higher (37.4± 0.99) altitude 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 (5.47±0.17) than North Lakhimpur (4.66±0.19), with the record of maximum weight in female (6.20±0.04) during spring and minimum in male (3.55±0.19) 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 (411.1±10.95 m and 48.08%) than Mokokchung (373.24±9.97 m and 43.59%), denier was recorded to be higher in Mokokchung (5.85) than North Lakhimpur (5.17).

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 diapason character of *A. assama* indicated its adaptability to severe winter at higher altitudes and would provide enormous opportunities for rearing of wild variety which may be cross breed with cultivated one for hybrid vigor and production of disease resistant high yielding variety.

The congenial climatic condition in Nagaland state particularly during spring, summer and autumn seasons is highly suitable for muga culture which may have tremendous potentialities to emerge as important subsidiary crop next to agriculture for livelihood. However the knowledge of muga silk production is very poor among farmers due to lack of transfer of technology, which is 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, revelers, 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 most important for any successful commercial crop.