CHAPTER- 2

REVIEW OF LITERATURE

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2.1 Overview of Sericulture

Sericulture refers to the conscious mass-scale rearing of silk producing organisms to obtain silk for personal and commercial use. Sericulture has been a part of life and culture of many civilizations since time immemorial. The practice of sericulture suits both marginal and small-scale landowners because of its low investment, short gestation period, high assured returns and rich prospects for enhancement of income and creation of family employment round the year. In the present scenario, sericultural sector is also considered as cottage industry par excellence by virtue of its agro-based, industrial super-structure and labour-intensive activities linking maximum number of family members.

Silk is produced in over 30 countries of the World of which 14 are situated in the Asian region (Jaiswal *et al*., 2008). Sericulture is one of the important sectors of economy in India as it plays significant important role in programmes of poverty alleviation. The sector provides more employment all-round the year as compared to agricultural crops and fetches more income for rural and economically backward communities. Besides being environmental friendly farm activity such as raising of perennial food plants, it also allows commercialization and diversification of farm enterprises. It is remarkable for its low investment and quick and high returns which make it an ideal industry or enterprise and fits well into the socio-economic fabric of India.

Indian sericulture is an age old practice; producing all the five commercially exploited natural silks viz., mulberry, muga, eri, tropical tasar and oak tasar. Sericulture is a source of livelihood and provides gainful employment in the rural areas, especially the women among several communities. Silkworm food plants also form an important eco-friendly component of an integrated farming system and more so under the non-mulberry or vanya silk sector as the sector encompasses cultivation and utilization of various tree species for rearing of silkworm. Sericulture is highly recommended to planners and administrators as one of the most effective tools for rural reconstruction and development of the rural society. In India, sericulture has been acknowledged as an important sector of economy, particularly because of its potential for strengthening the rural economy, employment and increasing export earnings. Till recently, sericulture was considered as a subsidiary occupation. Introduction of new technology of sericulture has led to making the industry a high remunerative cash crop and the step up in raw silk output being witnessed every year.

2.2 Ericulture and NE India

As the eri silk gained the market value, there has been increasing demand in production of eri cocoons. This has attracted the non-traditional states and other countries where the food plants of eri silkworm viz. castor and tapioca are cultivated in large scale as agricultural crops, to go for ericulture as a source of additional income by using a part of foliage without affecting the main produce and primary income from host plant. Eri silk, among all non-mulberry silks, is exploited to the maximum extent accounting for 63% of total non-mulberry silk production and 13% of the total silk production in India (Anonymous, 2014).

India is the largest producer of eri silk in the World as 96% of eri silk is produced in India. In India, the NE region is very rich in seri-biodiversity. Being a natural abode for a number of sericigenous insects and their host plants, sericulture is being practiced since the time immemorial (Gargi *et al*., 1994). Ericulture is the most predominant amongst sericulture in this region and is not only a tradition but also a living culture (Chowdhury, 1982 and 1984). Ericulture is an ideal activity for development as subsidiary occupation in providing supplementary income to a large number of rural hilly and tribal populations (Alok Sahay *et al*., 1997, Chaoba Singh and Suryanarayana, 2003 and Suryanarayana and Chaoba Singh, 2005). Vijayan *et al.* (2005) also described the congeniality of the climate for eri silkworm in NE region of India. Singh and Benchamin (2001) also conducted extensive studies and reported that the tribal people in Karbi Anglong, North Cachar hills, Kokrajhar, Goalpara, Kamrup, North Lakhimpur, Dhemaji, Morigaon, Nagoan, Golaghat, Jorhat, Sivsagar etc., in Assam; East and West Garo hills, East and West Khasi hills and Ri-Bhoi Districts of Meghalaya; Wokha, Mokokchung, Kohima, Tuensang, Zunheboto of Nagaland; Aizawl and Lunglei of Mizoram; Imphal, Thoubal and Churachandpur of Manipur; Lohit, Khonsa, Papumpare and Tirap of Arunachal Pradesh practice ericulture. Majority of the host plants of eri silkworms are available in the region and the agro climatic conditions have suited ericulture to this region.

The ericulture is a village craft and the rearing, spinning and weaving activities are handed over from one generation to the other as the eri silk fabric, unique in appearance and aesthetic in appeal and also the national dress of the Assamese in NE India. Ericulture is carried out traditionally during villager's leisure hours from stray castor plantations supplemented occasionally by other secondary host plants in case of shortage of leaves. Eri spinning and weaving are done by villagers in the spare time and required fabrics are woven for the families' consumption. As such, it is not an organized commercial activity like the culture of mulberry silkworm. For the tribals, the eri pupa is a delicacy and cocoon is a by-product. Since eri cocoons cannot be reeled, its yarn do not fetch a good price and it remained as a subsidiary household practice for the tribals in hills and plains of NE India. Eri cocoons are traded in sizeable quantities in the weekly market at the foot hills of Meghalaya and in Kamrup district of Assam. The establishment Spun Silk Mill at Jagiroad by the state government was a milestone in the history of eri culture in Assam. If required raw material are made available throughout the year, fine fabrics can be produced and marketed. Eri cut cocoons have development to be a cash crop with a sizeable market provided through cocoon co-operatives. Incentives have been provided with a view to extending ericulture to the rural areas of hills and plains. Cocoon cooperatives have been established for purchase and supply of cocoons to needy rearers and to the Spun Silk Mill. Marketing facilities have also been provided for finished yarn and fabric. With the improvement of cultural practices and organizational methods, there is a scope for expanding ericulture in the region (Chowdhury, 1982).

2.3 Ericulture and the Bodo community

Of the three silkworms prevalent in Assam, the ‘eri’ worm yields the cheapest form of silk. The eri silkworm derives both its scientific and its vulgar name from its attachment to the castor-oil plant, called ‘eri’ in Assamese. ‘indi’ in Bodo. The rearing of the muga and silk cocoons for the manufacture of various muga and silk clothes seems to have been an indigenous culture of the Bodos, which had been being maintained since the prehistoric time. Many centuries ago that the Vedic Aryans came to the NE India, the fore fathers of the Bodos seemed to have been rearing silkworms profoundly in this region (Goswami, 1974). The fading of the silkworms and the castor oil plants is a tradition of the Bodos and they gave much importance on this industry in the ancient time when the varieties of cloths were not available as in the present time. They planted sufficient castor-oil plants to feed the silkworms and produced huge cocoons out of which eri threads were spun to weave their necessary cloths. This economic activity carried on by the Bodos and the art of sericulture most probably made the ancient Assam famous as the land of eri and muga in the world (Kaushambi, 1981). Similarly, Teotia and Bajpeyi (2009) found that rearing of eri silkworms is almost a household affair among the Bodo community in Kokrajhar District of Assam. Eri rearing is conducted not only for its silk but also for relishing pre-pupae/pupa as one of the delicacies.

2.4 Biology and culture of eri silkworm:

2.4.1 Systematic position

The eri silkworm *Samia Cynthia ricini* Boisduval (Syn. *Samia ricini* Hab.; *Philosamia ricini* Hutt.; *Attacus ricinus*) belongs to the family Saturniidae under order Lepidoptera, class Insecta and is considered phyletically an old group having the characteristics mark of an eye spot with unfailing persistency. Seitz (1933) considered *Philosamia ricini* as a stunted form of domestication of its wild counterpart *Philosamia cynthia*. Several authors consider these as different form and specific name is given to them. Crotch (1956) mentioned a number of crosses of *Cynthia* in one species and does not regard inter-breeding of races as hybridization. The question of dealing *P. ricini* and *P. cynthia* as two good species is rather difficult, because one of domestication. The only indisputable fact is that, in spite of their possessing many similar features determined by close relationship, they are somewhat different in certain morphological, physiological, biological and ecological characters (Chowdhury, 1960). According to Seitz, the genus *Philosamia* contains about seven forms distributed all over India, possibly due to environmental changes the phenotype of moths is variable. Peigler (1992) stated that many authors have used the generic name *Philosamia* for this group. *Philosamia*, Grote (1874) is a junior objective synonym of *Samia* Hubner, 1819 and therefore, *Philosamia* is not an available name according to the International code of Zoological Nomenclature (1985) and the correct generic name of all species in this group is *Samia.*

Eri silkworm is a polyphagous and multivoltine sericigenous insect and 5-6 crops can be raised in a year based on availability of food plants and prevalence of favourable climatic condition. Rearing of eri silkworm has been practiced in NE India for the production of cocoons and protein rich pupae mainly on two primary food plants viz. castor and kesseru (*Heteropanax fragrans* Seem.), while the important secondary food plants include payam (*Evodia flaxinifolia* Hook.), tapioca (*Manihot utilissima* Phol.), borpat (*Ailanthus grandis* Roxb.) and gulancha (*Plumeria acutifolia* Poir.). The nutritive value or composition of leaves depends on host plant variety and environmental conditions such as growing seasons, temperature, duration of sunshine, fertility level and moisture content of soil etc., while the nutritional status of various food plants varies seasonally, based on its chemical constituents and nutritional level thereby influencing the rearing performance, productivity and quality of cocoons. It is mostly the suitable variety of food plants and quality of foliage that ultimately reflects on growth and development of silkworm with a significant role towards fecundity, hatching and effective rate of rearing (ERR).

2.4.2 Biology and life-cycle

The life-cycle of eri silkworm has four stages - egg, larva, pupa or chrysalid encased in a cocoon and moth or adult. A complete life-cycle lasts about 44 days in summer and about 85 days in winter. The silkworm is multivoltine in nature having five to six generations in year (Chowdhury, 1982).

Egg:

The eggs are oval in shape with a hard chitinous chorion of candid white colour with colorless glue and devoid of any markings. The egg colour generally changed from candid white to bluish just before hatching. Micropy placed in a slight depression at one extremity of the horizontal axis. The pattern of follicular imprints is very distinct. Cells are polygonal and inter-cellular space are small and respiratory spines present in between the cells (Jolly *et al.,* 1979 and Sarmah, 1992).

Larva:

The larva hatch out from the eggs generally in the morning hours after 9 to 10 days in summer and 14 to 15 days in winter at normal temperature. The larva is typically eruciform and has a hypognathus head with biting and chewing type mouth parts. The newly hatched larva is greenish yellow in colour, elongated and cylindrical in shape measuring about 5.0 × 10.0 mm and weighs about 1.5 mg. The body colour changes gradually to pure yellow by the end of the third day.

From the third instar onward the body colour segregates into yellow, cream, green or blue depending upon races. The fully mature larva which measures about 7.0 × 1.5 cm is translucent and covered with white powdery substances. Both spotted and unspotted larva are found. The spots are of various types; single, double, zebra and semi-zebra (Jolly *et al.,* 1979 and Chowdhury, 1982).

The tiny larvae tend to remain together and do not easily move about. The larvae feed ceaselessly and continue growing only stopping to shed their skins during the larval period. The larvae moult or shed off their skins four times and complete the larval period in five different instars. During moulting period they do not feed. Unlike other non-mulberry silkworm, eri silkworm does not eat the empty egg shell on hatching nor the cast off skin after moulting (Jolly *et al.,* 1979). They have a very poor gripping power. The mature larvae produce a rustling sound when rolled between the fingers and have tendency to move upward and away from the foliage.

Silk gland:

Larvae are reared for productions of silk. Silk is a secretion of a pair of large silk gland which correspond to salivary glands of insects. The single gland is a long, tubular structure folded in characteristic manner. The silk gland is the largest organ of the body and occupies almost the whole body of the mature larva. There are large secretary cells and spinning apparatus with press and tube (Chowdhury, 1982).

Cocoon:

The larva attains maturity at the end of fifth instar. At this stage the larva stops feeding and empties its alimentary canal by passing out the last excreta. The mature larvae search a suitable cocooning place on the Chandraki (mountage) to spin cocoon. The spinning starts with to and fro movement of the head. First the base of the cocoon is formed followed by the formation of sides and finally the upper part, but during these operations the head movement is irregular. The cocooning is completed in three to five days and the larva gets deeply embedded in the thick layers of silk.

Eri cocoons are elongated, soft, flossy, peduncle less, open mouthed and exhibit colour polymorphism being creamy white and brick red. The shape and size of cocoons vary according to host plant and type of cocoonage (mountage) used.

Pupa:

The larva metamorphoses inside the cocoon into pupa or chrysalid. The pupae are of obtect adectious type and brown in colour. The pupa is a prelude to moth stage with all the appendages of future moth such as compound eyes, wings, antennae, legs, genitalia etc. which can be seen in bold relief. The female pupae are heavier than the male. The colour of pupae turns black before emergence of moth and there is harp movement of posterior portion of the abdomen.

Moth or Adult:

The eri silkmoths are stout, brownish or blackish in colour and covered with white scales. The male moth is smaller than the female. Wings two pairs, buff coloured with white coloured strips in the marginal portion. Wings covered with scales of different colours and shape. Veins prominent and visible from both sides. Forewings longer and narrower than hind wings. The forewings of both sexes are more or less similar in structure and colour pattern. The characteristics anti-median line is bright chocolate coloured with a white border on either side and almost runs through the centre. The post median line is black with a single dull grey border on either side. A conspicuous black spot, the plerostigma with a whitish tinger is present at the top of the wing apex. In additional the wing has a few white oblique lines. The ocellus in both sexes is crescent-shaped and is characteristic of the insect. The hyaline area is almost invisible and located in the most anterior region of the ocellus. The space between the ocellus and post median line is darker. The remaining colouration of both fore and hind wings is identical except the yellow strips of ocellus which is broader and prominent in hind wings (Jolly *et al.*, 1979 and Sarmah, 1992).

The emergence of moth takes place after about two weeks of pupal stage. The moth bores its way out through the open end of the cocoon in the morning hours and continues till mid-day. In the process, male moths emerge earlier than female moths. Soon after emergence they emit a creamy opaque liquid and within an hour they become fully active and prepare for mating. The freshly emerged earlier healthy female moths are collected and tied on 'Khariks's' - a straw stick with a hooking arrangement at the proximal end for convenient egg deposition and are hung on strands of wire stretched across the grainage room. Either the male moths are positioned by hand or they themselves approach the virgin female moths for coupling. Maximum pairing takes place during evening hours and the moths remain coupled for twenty four hours although three to six hours are adequate for good pairing. The males are then separated and decoupled fertilized female moths are left on the Kharika for egg deposition. Egg laying starts after about one to two first two days are considered for rearing. The eggs are deposited vertically in a single layer at two or three places on the Kharika.

2.4.3 The Culture:

Host plants:

The silkworm is polyphagous and feeds on leaves of various plants mainly belonging to the family Euphorbiaceae, Araliaceae, Apocynaceae and Simarubiaceae (Chowdhury, 1982). Castor (*Ricinus communis* L., $2n = 2x = 20$, Euphorbiaceae) is the most preferred food plant for rearing of eri silkworm (Ghosh, 1949 and Fukuda *et al*., 1961). Kesseru (*Heteropanax fragrance)* is utilized next in this region. The other secondary food plants are tapioca (*Manihot utilissima),* Borpat (*Ailanthus grandis*), Borkesseru (*A. excelsa*), Korha (*Sapium eugenifolium),* payam *(Evodia flaxinifloia),* Gulanch *(Plumeria acutifolia),* Gamari (*Gmelina arborea*), Bajramani (*Xanthoxylum rhesta)* etc. (Singh and Das, 2006; Chakravorty and Neog 2006; Bhattacharya *et al.*, 2006; Das *et al.,* 2006; Chowdhury 2006 and Bindroo *et al.,* 2007). Leaves of secondary and tertiary food plants are used as alternate food when primary host plant become scarce (Chowdhury, 1982). The growth, development and economic characters of silkworms are influenced to a great extent by a variety of food plants and nutritive contents of foliage (Singh and Das, 2006).

High yielding food plant plays a significant role in development of sericulture industry (Debaraj *et al.,* 2003). Although, a large number of different castor genotypes exist in nature, a superior castor variety has to be identified for commercial cultivation. Systematic molecular diversity study of castor inbreeds or parental lines showed polymorphism ranged from 33.3% to 100.0%, with an average of 68.1% through ISSR primers (Gajeraa *et al.,* 2010). So, selection of a high yielding castor variety(s) is need of the hour to boost the ericulture at farmers' level. In order to evaluate suitable castor genotypes for eri silkworm rearing, several attempts have been made by different investigators (Sarkar, 1988 and Chakravorty and Neog, 2006).

Castor is an industrially important non-edible oilseed crop broadly cultivated in some of the arid and semi-arid regions of the world (Govaerts *et al.,* 2000). Castor oil, which has a long history of use for medicinal purposes is considered a promising raw material for the production of renewable energy in some of the tropical countries (Gaginella *et al.,* 1998). Besides, castor bean has been traditionally cultivated for the production of lubricants and paints (Ogunniyi 2006; Scholz and Silva, 2008 and Berman *et al.,* 2011).

India is the largest producer of castor in the world and also one of the centres of castor diversity, where great diversity exists across the country in varied ecosystems (Anjani, 2012). It is usually cultivated as a hybrid in India, which gives significantly greater yields than pure lines or varieties (Birchler *et al.*, 2003 and Reif *et al.*, 2007).

With more than 95% of the world's castor production concentrated in limited parts of India, China and Brazil (Sailaja *et al.*, 2008) and because of ever increasing worldwide demand, there is a pressing need to increase productivity of castor biomass as well as seed. Therefore, the production of leaf biomass and oil seeds with high yielding variety and appropriate agronomical recommendation is a promising task for both the industries.

Castor is greatly exploited for eri silk production in nontraditional States of India whereas tapioca, the most preferred food plant after castor has also been proved to be suitable for commercial rearing (Sakthivel, 2012). Tapioca is cultivated over 2.32 lakh hectare in the country. The southern states *viz.* Kerala, Tamil Nadu and Andhra Pradesh together account for 88.65% of total tapioca cultivation and have great potential to enhance the nation's eri silk production.

2.5 Nutritional constituents of food plants:

The requirement of nutrients for growth and survival of silkworm larvae have been demonstrated both quantitatively and qualitatively (Legay, 1958; Yokoyama, 1963 and Yashiro *et al.*, 1985). Ito (1967) and Horie (1978) also elucidated the essential nutritional requirement of the silkworm larvae. Silkworm derives nutrients from their host leaves, as such biochemical properties of host leaves have great significance in determining their food value. Tanaka (1964) reported that the carbohydrate values showed a positive relationship with leaf age.

Vasuki and Basavanna (1969) studied that the protein content of mulberry leaves differs with the maturity of leaves. Generally young leaves are more acidic than older leaves. Accumulation of protein in silkworm depends largely on the carbohydrates in the leaves. They reported that the composition of mulberry leaves varies with variety, degree of maturity and the type of soil in which the plants are grown.

Ito and Kobayashi (1978) started that moisture and protein content of mulberry leaves decreased with maturity of leaves while carbohydrate contents increased with leaf age. Mineral content present in the mulberry leaves are approximately 10 per cent and about 28 per cent of the total ingested minerals throughout the larval period of silkworm, *B. mori* are retained in the body substance. He also revealed that chemical composition of mulberry varies depending on variety, season, temperature, nature of soil, kind of fertilizer, level of ground water and method of cultivation etc.

2.6 Rearing techniques:

Eri silkworms are reared in indoor condition. The eggs are kept in the rearing tray on a piece of paper before twenty four hours of hatching. They are covered with a few tender leaves when they start to hatch. The larva crawls gradually on to the underside of the leaves and remain very close together in groups. It is advisable to feed them with chopped leaves until the first moult as they may become enclosed on the dried leaves and discarded at the time of cleaning. Extreme care is taken to ensure that age of the leaves is compatible with the growth stage of the larvae. They should not be fed wet, dirty, diseased, dried or ripe yellow leaves or offered too many leaves at a time. The plucked leaves are loosely heaped and kept covered with wet gunny cloth to maintain the freshness of the leaves. The density of the larval population should be properly regulated.

The larvae are reared on trays or on bunches of leaves. If fed on trays whole or chopped leaves are spread over the larvae. Considerable time is saved, but the rearing bed becomes dirty with excreta. In any case, this method is necessary until the second moult. In the bunch method of rearing, eight to ten leaves are tied together and hung on a stick resting across the two parallel bars of the stand. The vertical position of the leaf lamina not only facilitates almost complete consumption of the foliage, but also permits the litters to drop directly on to the tray underneath without soiling the leaves. This feeding method thus combines foliage economy and cleanliness. Up to the third instar the larvae are given four feedings per day and the late instars fed five times a day at regular intervals. The rearing bed should always be cleaned to maintain hygienic condition during rearing period and healthy development of larvae. The rearing generally conducted under normal room condition in all the seasons. As soon as the larvae mature they are mounted on the Chandrakin for concoon spinning. The larva takes three to four days to spin the cocoon completely. After about five to eight days the cocoons are harvested from the Chandraki.

2.7 Rearing performance on leaves of castor and tapioca

Almost all insects are host specific and selects their most preferred food in order to extract the maximum benefit out of it, although most of them eat a great many varieties (Brues, 1946). The host plants have profound effect on survival, rate of food intake, digestion and assimilation which directly influence the growth and development of silkworms. The amount and quality of food intake of larvae influence different parameters like growth rate, larval duration, survival rate and reproductive potential (Waldbauer, 1968; Bhattacharya and pant, 1976; Das and Das, 2003 and Kumar and Elangovan, 2010). Raychaudhury (1974) stated that the quality of leaf influence the growth and development of silkworm and overall silk production. Scriber and Slansky (1981) and Slansky and Scriber (1985) critically reviewed these aspects of nutrition ecology of insect and concluded that nutritional indices as well as growth and development of insect varied on different host plants.

Dietary efficiency of the food plants from which the silkworm derive their nutritional requirement depends upon their chemical makeup. Most of the food plants may contain all the nutritional requirements but the quantity of each nutrient may not be well balanced for proper growth and development of silkworm. Quantitative requirements for each nutrient and the required balance of nutrients for optimum nutrition may vary within and between species owing to many factors including synthetic ability of the insect and metabolic activities involving specific interrelations between certain nutrients (House, 1974). Thus, studies on quantitative and qualitative aspects of insect nutrition is much essential for better understanding of the insect-plant relationship and is of great importance for improvement of diet of the silkworm through selection of food plants.

Literature contains a few studies on effect of different food plants in nutritional ecology and economic aspects of eri silkworm (Joshi and Mishra, 1979; Joshi, 1986; Pathak, 1988; Joshi, 1992 and Dutta and Kalita, 1997). These studies revealed the superiority of castor in respect of quantitative nutrition, larval growth and cocoon characters. Pandey (1995) also opined that, nutritional status of leaves has been implicated as major factor in the survival of non-mulberry silkworms.

Chandrashekhar *et al.* (2013) opined that the foliar contents of major and secondary nutrients may vary from region to region and also season to season. Pandey (1995) studied on seasonal variation in Oak leaf quality of *Quercus serrata* and its impact on oak tasar silkworm rearing and revealed that leaf proteins was high between March and April and then declined in summer and autumn months. Conversely, crude fibre content was minimum during March. During spring (March) the moisture content was highest along with carbohydrate and crude protein while during April, the leaf moisture decreased with increase of crude protein and mineral contents.

The productivity and quality of cocoon, however, depends upon quality food supply, favorable environmental conditions and utmost hygienic condition (Yadav and Mahobiam, 2010). Seasonal variation such as variation in temperature, humidity, sunshine, rainfall, etc. of a particular place, which is governed by different geographical parameters influences the rearing performance of silkworm (Murthy *et al*., 1996; Clarke 2003; Tamiru *et al*., 2012 and Bhatia and Yousuf, 2014).

Insect, being cold blooded organisms, the performance of all insect species solely depends on temperature changes (Singh *et al*., 2009 and Petzoldt and Seaman, 2013). The ideal range of temperature for the growth of eri silkworms ranges from 20°C to 40°C, however, increase in temperature beyond 35°C causes less spinning, mortality of larvae and pupae and poor moth emergence and sterility at adult stage (Sugai and Takashashi, 1981 and Sahu *et al.*, 2006).

Tanaka (1964) reported that crude protein of mulberry leaves decreased with the advancement of leaf maturity. Rupa *et al*. (1993a) worked on positional nutrient status of mulberry leaves and observed that the concentration of organic constituents in the mulberry leaves such as crude protein, non-reducing sugar and total sugar was significantly higher in tender leaves than in medium and mature leaves. Sinha *et al.* (1993) analyzed the variation of chemical constituents in relation to maturity of leaves of mulberry varieties under the agro-climatic condition. They opined that the values of moisture, total nitrogen, total minerals and crude fibre generally decreased gradually with maturity of leaves.

Rupa *et al.* (1993a) also studied the effect of soil properties in nutrient constituent of mulberry leaves and established that the nutrient of mulberry was significantly influenced by the available soil nutrient status.

The quality of leaves provided to the worms for feeding is the prime factor influencing the production of good cocoon crop. Pandey (1995) observed that factors like growth, development and cocoon yield are influenced by the castor genotype and quality of leaves fed to the worms. Nutritional grade of leaves has been considered as a major factor in the survival of non-mulberry silkworms. Ravikumar (1988) and Sarmah *et al*. (2011) opined that better the quality of leaves, greater would be the chances of getting the good cocoon harvest.

Leaves of castor is rich in varietal composition and many local and high yielding varieties are widely grown in Assam and other parts of the country. The choice of castor genotypes is an important aspect for better growth and development of eri silkworm for higher output in terms of cocoon yield. It has also been observed that the silk ratio varies with the type of host and eri silkworm breed used for rearing (Dookia, 1980). Chandrasekhar *et al.* (2013) and Sakthivel (2016) also reported significant variations in nutritive value of leaves in different genotypes of castor.

Kaleemurrhaman and Gowri (1982), Basaiah (1988), Sannappa and Jayaramaiah (2002), Govindan *et al.* (2003a and 2003b) and Chandrappa *et al.* (2005) observed some variations in moisture content of leaves among the castor genotypes. Variation in moisture content among different genotypes could be attributed to their inherent characters. The rise in leaf moisture content may be due to the increase in hydrogen ion concentration of plant sap due to gathering of chlorides and less moisture loss by evapo-transpiration (Eaton, 1942). According to Sastry (1988), leaf moisture and its retention for longer duration increases the feeding efficiency resulting in enhancement of growth rate of silkworm larvae. These results are in conformity with the observations of Kaleemurrahman and Gowri (1982), Sannappa and Jayaramaiah (2002) and Chandrappa *et al.* (2005) who observed variations in moisture content of leaves among the castor genotypes.

Kaleemurrahaman and Gowri (1982), Basaiah (1988), Sannappa and Jayaramaiah (2002), Govindan *et al.* (2003a and 2003b) and Chandrappa *et al.* (2005) also recorded variation in crude protein content among castor genotypes raised under rainfed situation. They also observed variation in the total carbohydrate content among the castor genotypes.

Jolly (1981) estimated the chemical components on the leaves of different mulberry varieties and reported that local variety of mulberry possessed the highest amount of mineral content than all other varieties. Bose *et al.* (1991) made a comparative biochemical study of six mulberry varieties. The study revealed that mulberry varieties vary in their nutrient constitutions.

Pathak (1988) studied consumption, utilization and growth rate of eri larvae on different food plants *viz.,* castor, kesseru, tapioca and gulancha and observed that consumption index was significantly lower on castor leaves and higher on gulancha. The relative growth rate of larvae was highest on castor followed by kesseru, tapioca and lowest on gulancha. The approximate digestibility and co-efficient of apparent digestibility of crude protein were lower on tapioca and gulancha, while the larvae reared on kesseru and castor exhibited higher digestibility in terms of both food and crude protein.

Sinha *et al.* (1986) analyzed the foliar constituents of three food plants of temperate tasar silkworm, *Anthereae proylei* J. viz. *Quercus himalayana, Q. dealbata* and *Castenea sativa* and reported that the food plants of *A. proylei* vary from one another in their chemical constituents. Pandey and Goel (1991) studied the constituents of the young and old leaves of some oak-tasar silkworm food plants and demonstrated that nutritive value of oak tree foliage declines in protein in content and increase in fibre.

Pathak (1988) estimated the composition on the leaves of different food plants of eri silkworm and reported that the moisture content was highest in gulancha followed by tapioca, kesseru while it was lowest in castor. Crude protein content was highest in castor and lowest in gulancha. Crude fat, total soluble in sugar and reducing sugar contents were highest in kesseru. While the lowest amount of crude fat was recorded on gulancha. Tapioca leaves possessed lowest amount of total soluble sugar and reducing sugar content. In all the food plants leaves moisture and crude protein content decreased gradually with the maturity of leaves while crude fat, soluble sugar and reducing sugar increased gradually with the age of leaves.

Dutta *et al.* (1997) analyzed the foliar constituents of four different food plants of muga silkworm, *A. assama* and found differences in values of nutrient constituents. With significantly low percentage of crude fibre and high amount of total nitrogen, protein, starch and calcium contents, mezankari (*Listaea citrata*) leaves were best in nutritive value followed by som (*Machilus bombycina*) and soalu (*L. polyantha*) leaves. Digloti (*L. salicifolia*) occupied the last position in these respects.

Shaw (1998) analyzed the chemical composition of three *Ailanthus* species in relation to growth, nutrition and cocoon characters of eri silkworm and found that with higher amount of moisture, total nitrogen, crude protein, crude fat and lower amount of crude fibre, *A. grandis* emerged out as the most efficient host plant for rearing of eri silkworm as it contribute maximum to the larval growth rate, and all larval growth and economic cocoon characters of the silkworm than *A. excelsa* and *A. altissima*.

Srivastava *et al.* (1998) studied on foliar characters and constituents in spontaneous hybrid genotypes of *Terminalia* (Pentatera) for tasar culture and revealed that the spontaneous hybrid genotypes of *T. arjuna* and *T. tomentosa* vary significantly in respect of total minerals, total carbohydrate and total nitrogen contents.

Hazarika *et al.* (1995) determined the quality of som leaves for rearing of muga silkworm, *A. assamensis* and found that there was significant variation in soluble protein, soluble sugar and total phenol in the leaves of five different som plants. Best quality showed the highest amount of soluble protein and total phenol while poor quality plants contained lower quantities of total phenols and soluble proteins. However, soluble sugar content did not show any such positive relationship with feeding behaviour of muga silkworm.

4.2 Rearing performance of eri silkworm on the leaves of castor and tapioca during different seasons and the quality of cocoons and silk yarns produced

A. Studies on effect of host plants on rearing performance of eri silkworm during different seasons:

The influence of variations in nutrient values of mulberry varieties on the mulberry silkworm was also documented by Sujathamma and Dandin (2000). The nutritional status in the leaves of food plants which influences the economic characters of silkworm crop depends upon the level of moisture, total protein, total carbohydrates and total minerals (Bongale and Chaluvachari 1993).

Reed *et al*. (1982) reported that the increased level of tannin caused reduced intake of leaves and digestibility in silkworm. Ravindran and Ravindran (1988) also reported the presence of antinutrients which interfere with digestibility of nutrients, these antinutrients might present toxic effects depending on the amount consumed (Alessio *et al*., 2002). The analyses carried out on tapioca leaf varieties showed that tapioca leaves contain mineral elements and phytochemicals that are of nutritional and biochemical importance to humans and animals. However, the main limiting factor to the use of tapioca leaves as animal feed is the presence of cyanogenic glucoside, which gives rise to hydrocyanic acid (HCN) when the plant tissues are broken down during various metabolic processes in the body of animals (Ravindran, 1995). Therefore, the use of appropriate processing techniques could help reduce or eliminate the adverse effects of these antinutrients and will improve their nutritive value (Ogbuji and David, 2016).

Studies have also shown that the larval duration was relatively short during July - August (Monsoon) rearing than winter season and also recorded minimum pupal period, less cocoon weight and shell weight (Virk *et al*., 2009). Similarly, found highest hatching percentage, larval weight, cocoon weight, shell weight, silk ratio and minimum larval period during August-September rearing season (Hata *et al*., 2005). Other researchers have also recorded maximum hatching percentage (98.40%) during September-October, maximum moth emergence per cent (98.70%) during November-December (Ravishankar *et al*., 2000).

Nangia *et al.* (1998), Devaiah *et al.* (1985), Dayashankar (1982) Chowdhary (2006), Rao *et al.* (2009) and Anjani *et al.* (2010) reported that the castor fed larvae yielded highest larval weight, ERR, silk content percentage than tapioca. Biswas and Das (2001) stated that the food plant influenced the larval growth, larval duration, cocoon weight, pupal weight, shell weight, SR, ERR and fecundity, when larvae were fed with castor and larval duration was shorter. Chakravorty and Neog (2006) reported suitability of different eri food plants viz. castor, kesseru, tapioca and payam and appraised the suitability of castor in terms of fecundity, larval weight, cocoon weight and shell weight. Hazarika *et al.* (2003) studied that castor was found best in terms of different parameters viz, nutritive value of larva, larval weight, ERR, cocoon weight, shell weight, pupal weight, fecundity, hatching percentage and larval duration was found shorter on castor fed leaves.

Sarmah *et al*. (2011) analyzed the biochemical properties and rearing performances of eri silkworm and found positively correlated larval weights with lipid and sugar contents and negatively with leaf nitrogen and protein contents. Anjani *et al.* (2010) established a significant positive association between total phenol content and insect resistance where phenols were known to play an important role in plant defense against harmful insects which has been established in several crops. The weights of larvae and cocoons were significantly influenced by nitrogen and crude protein content of foliage and free amino acids (Vijaykumar *et al*., 2009).

Protein content in leaf is a major source for silkworm to synthesize the silk which consists of two proteins namely fibroin and sericin (Rangaswami *et al*., 1976). Similarly, Bongale and Chaluvachari (1995) also opined that, protein content of mulberry leaves has a profound impact on larval growth particularly in silk gland development and cocoon characters of silkworm.

Sugar plays an important role in determining the quality of leaf that in turn influences growth, development and health of silkworm. As per Horie (1978), more carbohydrate content in leaves is helpful in producing fat body glycogen which in turn increases the trehalose content in haemolymph.

Sarmah *et al.* (2011) recorded variations in phenol content among different castor varieties. Rao *et al.* (2009) reported that high phenol content in castor leaves affects feeding of silkworm during rearing. It indicated that lesser the phenol content in leaves better the growth, development and survival of silkworms as these were reported as anti-nutritional in properties. Alugah and Ibraheem (2014) shown the distribution of flavonoids and tannins in castor plant and revealed their antioxidant, antihemolytic and antibacterial effects.

Tannins are groups of plant polyphenolic high molecular weight secondary metabolites. The name tannins came from the French word "*tan"* meaning the bark of the Holm oak tree used for tanning and have been found to be present not only in the tree bark but also in leaves, stems, roots, buds and seeds (Frutos *et al*., 2004). They create dry, astringent and bitter taste in mouth when consumed in unripe fruit, strong tea or red wine (Ashok and Upadhyaya, 2012). Tannins like other phytochemicals possesses lots of medicinal benefits to human, such as stated previously in addition to been used in the treatment/control of diarrhea, rhinorrhea and leucorrhoea, treatment of wounds and burns, stoppage of bleeding, for sun screen or ultra-violet ray protection, combating obesity by its ability to increase digestion (Hagerman, 2002 and Briskin, 2014). There exist very limited information as regards the quantity and biological activities of flavonoids and tannins present in this plant (Kensa and Syhed, 2011; Taur and Patil, 2011; Naz and Bano, 2012; Jeyaseelan and Jashothan, 2012; Khursheed *et al*., 2012 and Vandita *et al*., 2013).

The food quality relevant to growth, development and reproductive potential depends mainly on nutritional composition, which includes both the absolute and relative amount of water, carbohydrates, proteins, amino acids, lipids, minerals, etc. (Slanky and Scriber, 1985). Similarly, Ravikumar (1988) also reported that rich harvest of cocoons is ensured when superior quality of leaves are fed to the silkworms. It is also reported that 25 to 30 per cent of foliage from castor plantations can be utilized for eri silkworm rearing without affecting the seed production. Therefore, ericulture can be a supportive economy for the poor and may also provide gainful employment to the women (Raghavaiah, 2003 and Rao *et al*., 2004).

Several studies have reported that the foliage constituents have a positive correlation with the cocoon parameters such as weight, shell weight, etc. (Dutta and Khanikor, 2005 and Singh *et al*., 2012). The variation in ERR may be due to the presence of different nutritional contents and fiber content etc. on the leaves of food plant during different seasons.

Similarly, increase of larval weight, cocoon and pupal weight and SR exhibited by eri silkworm fed on castor leaf have been correlated with higher rate of food ingestion, food assimilation and respiratory activity (Kumar and Elangovan, 2010).

Sastri (1962) extensively investigated the relationship between composition of mulberry leaved fed to the larvae and resultant silk production and observed that accumulation of protein in larvae depends largely on the concentration of carbohydrate in the leaves.

Ueda and Suzuki (1967) elucidated the mutual relationship among the amount of food ingested, digested and digestibility in temperate silkworm, *B. mori* and revealed that the amount of food ingested increases more rapidly than digested and the digestion ratio becomes lower in proportion to the increase in accumulative amount of food digested.

Yamamoto and Gamo (1976) observed a significant positive correlation between ingesta and cocoon weight, shell weight and larval weight in silkworm, *B. mori*, while Yamamoto and Fujimaki (1982) encountered negative correlation between cocoon shell weight and ingested dry matter for production of a unit cocoon shell weight. The relationship of amount of food intake and cocoon productivity was also studied by Takano and Arai (1978).

Shamachary *et al.* (1980) reported that ratios of cocoon weight, pupal weight and shell weight were dependent on the weight of full grown larvae. They also found that 54.5 per cent of the weight of full grown larvae could be expected in terms of cocoon yield and 1.4 times the shell weight could be expected to be the total weight of eggs to be produced by a silkmoth.

Li and Sano (1984) studied the relationship between quality of mulberry leaves and economic characters of silkworm and observed that high quality of carbohydrates and lower levels of water and proteins in the feed resulted in slower larval growth, less body weight and cocoon weight.

Joshi (1985a) studied the relationship between food consumption and fecundity of eri silkworm and observed that food consumption had positive relationship with fecundity. Maximum food consumption of castor resulted in maximum fecundity while less consumption of food on tapioca resulted in less fecundity in moths.

Singh and Prasad (1987) worked on correlation among body weight, pupal weight and fecundity in eri silkworm, observed that there was significant and positive correlation between different pairs of characters viz. body weight and potential fecundity, pupal weight and fecundity, pupal weight and potential fecundity and body weight and longevity.

Nagalakshamma *et al.* (1988) studied the variation, correlation and regression of eri cocoon and found highly significant association of cocoon weight with pupal weight and shell weight. The pupal weight was moderately associated with shell weight. Shell ratio percentage was decreased with increase of cocoon weight in general.

Govindan *et al.* (1992) studied the relationship between pupal size and egg production in eri silkworm and observed that the number of eggs laid by the female moth was correlated with the pupal measurement like pupal weight, body length and body width.

Paul *et al.* (1992) made a study on impact of dietary moisture on nutritional indices and growth of *B. mori* and concomitant larval duration and found a high degree of correlation between larval weight and leaf moisture content. They also reported that absolute consumption of food and growth rate of larvae increased with increasing level of leaf moisture content.

Magadum *et al.* (1996a) studied the correlation among various nutritional parameters of silkworm, *B. mori* during 5th instar larval development and found that there was significant mutual relationship between total ingesta and total digesta, mature larval weight, larval duration and fecundity. The total ingesta were related to total digesta, mature larval weight, larval duration, cocoon weight, shell weight and fecundity.

Chaluvachari and Bongale (1996) studied on bioassay moulting response of silkworm, *B. mori* in relation to leaf nutritive constituents of mulberry genotypes reported that leaf sugar content existed negative correlation with moulting ratio and higher leaf protein content associated with higher leaf protein content associated with higher values of moisture content and moisture retention in the leaves favoured the moulting ratios and larval weight.

Jayaramaiah and Sanappa (1998b) revealed that in eri silkworm, the larval duration, weight, survivability and ERR have significant positive relationship with moisture, total carbohydrates, total amino acids, phosphorus, potassium, calcium and magnesium content of castor leaves. There also existed positive significant relationship between above foliar constituents and weight of cocoons, pupae, shell weight and shell ratio.

The quality of leaves particularly the moisture content, nitrogen, protein, minerals, crude fibres, sugar and starch contents play a significant role in the proper growth and development of silkworm (Kohli *et al.*, 1969, Sinha and Jolly, 1971 and Pathak, 1988). Pathak (1988) studied the presence of fatty substances in the leaves of castor, tapioca and *Plumeria acutifolia*. Agarwal *et al.* (1980) found considerably low percentage of fat in tasar food plants.

Pathak and Dutta (1990) reported that food plants had significant effect on larval weight, larval duration and cocoon characters on eri silkworm. It was evident that higher larval weight gain, shorter larval duration, higher cocoon weight, shell weight and shell ratio on castor indicated its superiority as principal host plant for rearing of eri silkworm, kesseru was next after castor fulfilling all the above criteria followed by tapioca. Gulancha was least preferred variety of eri silkworm.

Giridhar and Sivarami Reddy (1991) evaluated the performance of parental bivoltine *B. mori* breeds on different mulberry varieties during different season and observed that weight of larva, cocoon and shell were more during rainy season.

Govindan *et al.* (1992) studied the economic traits and growth indices of eri silkworm, as influenced by substitution of castor with three other food plants. The study revealed that eri silkworm reared exclusively on castor exhibited superiority in larval, cocoon and seed technological traits followed by the worms reared upto the end of the fourth instar on castor and in the fifth instar on tapioca leaves. They also worked out the growth indices of the silkworm such as growth, larval weight, larval duration, cocoon spinning, cocoon weight, silk, pupal and oviposition for different food regimens involving the combination of castor with tapioca, *Plumeria alba* and *Ailanthus excelsa*.

Hazarika and Hazarika (1996) assessed the preference of local and high yielding varieties of castor for eri silkworm. Patil *et al.* (1998) studied the performance of eri silkworm on different castor genotypes. The influence of castor genotypes on rearing performance of different eri silkworm breeds have also studied by Jayaramaiah and Sannapa (1998a).

Sharma *et al.* (1998) worked out the effect of three different food plants viz. castor, kesseru and borpat on certain life parameters of eri silkworm and observed that castor feeding increased fecundity and adult longevity of eri silkworm. Shell weight and shell ratio were also increased due to castor feeding during spring and autumn. Summer rearing on borpat increased shell weight and shell ratio. The food plants did not differ in respect of larval weight, larval period, pupation success, growth index, incubation period and egg hatchability of eri silkworm.

Several studies have also been made by several workers on larval growth and cocoon characters of eri silkworm on different food plants in relation to larval growth and cocoon characters (Thangavelu and Bora, 1986 and Hazarika, 1989). Kapil (1967) studied the effect of feeding different castor varieties and tapioca on the growth and cocoon weight of eri silkworm and observed that increase in weight showed variation within the group of all the development stages of the larvae, feeding on castor leaves. The increase seemed to be much lower for the larvae eating tapioca leaves. The age of plants does not influence the food value of the castor leaves.

Joshi and Mishra (1979) worked on live weight of larvae, cocoons, pupae and silk content of eri silkworm reared on interchanged castor and tapioca. Devaiah *et al*. (1988) also studied the effect of castor, tapioca and their combinations on the growth and development of larvae and cocoon characters of eri silkworm and reported that the larval, pupal and shell ratio percentage were superior when the larvae were fed with tapioca upto second instar and subsequently on castor. The larvae fed on castor showed higher cocoon, pupal and shell weight and shell ratio percentage compared to the larvae fed on tapioca alone.

Dookia (1980) studied the silk yield of eri silkworm with six different castor varieties in Rajasthan. Dookia (1986) also studied castor varieties of Assam local, Bihar local and Udaipur local varieties. Viswakarma and Thangavelu (1981) observed that the differences in larval weight of eri silkworm on various food plants was evident only during certain months. The larvae fed on castor showed the highest weight while lowest was on tapioca. The larval period did not vary much on different food plants. The economic cocoon characters such as cocoon weight, shell weight and silk ratio in a particular season were dependent on the corresponding larval weight. The influence of food plant on cocoon characters was non-significant.

A great deal is known concerning the qualitative nutritional requirement of insect. However, the quantitative aspects of insect nutrition have received less attention and there have been only few studies on the rate of food intake and efficiency of food utilization of food by silk producing insect like mulberry silkworm and eri silkworm. Hirtsuka (1920) observed that the average digestibility of dry matter during the whole larval stage of mulberry silkworm was 40.9 per cent. This figure was highest in the first instar but the food intake of this instars was only 0.08 per cent of the total. The food intake of the fifth instar was 85 per cent of the total, but average digestibility was at its lowest in this instar.

Yokohama (1962) revealed that young larvae of mulberry silkworm at only 10 to 20 per cent of mulberry leaves given to them while grown up larvae ate 60 to 70 per cent or even more. A single larva could eat about 20 g of mulberry leaves until it became a mature larva, taking about 85 per cent of them at fifth stage. The amount of digesta was larger in grown up larva than in younger ones, but digestibility was higher in younger larvae than in grown up ones, which accounted to 50 per cent and 35 per cent respectively in terms of dry matter. About 25 per cent of the digested amount of leaves in terms of dry matter became silk substances, which corresponded to about 10 per cent of the dry weight of ingested leaves.

Poonia (1978) studied the food utilization and growth rate during developmental stages of eri silkworm and observed that the cumulative live weights and food intake increased with age at a much faster rate than that of larval weight. The food utilization showed an inverse relationship with age, the maximum utilization occurred in early stages (II and III) which tappered in later (IV and V) stages. The rate of growth showed four epoches in the growth pattern, the first consisted of an initial slow rate of growth; the second was characterized by a rapidly accelerated rate leading to a peak, believed to be the peak of vegetative growth; the third consisted of a steady deceleration and the fourth consisted of a short rise again, leading to another but dome shaped peak as believed to be the peak of reproductive growth which was lower than the first.

Ito and Kobayashi (1978) stated that single larva of mulberry silkworm consumed approximately 5 g of mulberry leaves on dry weight basis and approximately 88 per cent of them were ingested during the last instar. Digestibility was higher in the younger larvae but lowered down with larval ages.

Benchamin and Jolly (1984) and Ramadevi *et al.* (1992) studied on ingestion, digestion and conversion efficiency in polyvoltine and bivoltine breeds of mulberry silkworm and revealed that utilization efficiencies are breed dependent.

Horie and Watanable (1985) investigated the daily utilization and consumption of energy in food by the mulberry silkworm and estimated the distribution of energy absorbed in the body of the larvae, pupa, adult, egg and cocoon. The amount of energy ingested and absorbed during the fourth and fifth instars was 24.7 and 11.7 Kcal for the male larva and 28.5 and 13.6 Kcal for the female counterpart. The utilization of energy was recorded to be 47-48 per cent. Energy gain in a larvae was 6.7 and 7.9 Kcal for the male and female respectively during the same period.

Basaiah *et al.* (1990) studied the consumption and utilization of castor and tapioca by the larvae of eri silkworm and revealed that consumption index decreased with age. Rate of ingestion of the food plants did not differ significantly on fresh weight basis but significantly higher rate of ingestion was on tapioca on dry weight basis. Approximate digestibility of food decreased with the age of larvae growth rate increased till the fourth instar and decreased abruptly during the fifth instar.

Ananth Raman *et al.* (1993) studied on nutritional efficiency in mulberry silkworm and revealed that the amount of dry matter ingested and digested in different instars were significantly different.

Dutta *et al.* (1996) evaluated that the nutritional efficiency of two multivoltine breeds of mulberry silkworm native to Assam and observed that the growth rate and conversion efficiency of ingested as well as digested food to the body matter of the breeds were better in spring season even though the rate of intake was lower in this season. The breeds were at par and season had no effect so far as food digestibility was concerned.

Dutta and Kalita (1997) worked on food consumption and utilization by the larvae of eri silkworm on different food plant revealed that with lower rate of food consumption, higher percentage of approximate digestibility and higher efficiency of conservation of ingested and digested food to body biomass castor was utilized best for better growth of the larvae. Kesseru was next to castor followed by tapioca and borpat rated as inferior food plant in terms of nutrition to the eri silkworm.

Tensile properties of silk fibres and yarns

High tenacity, low elongation etc. are among the important qualities of silk fibres (Peter, 1970; Moncrieff, 1975 and Munro, 1987). Silkworm silk is the strongest natural protein fibre, it is stronger than an equal-diameter filament of steel (Crotch, 1956).

The strength of any textile material is largely governed by two important testing parameters viz., extension rate and gauge length (Ghosh *et al*., 2005). The tenacity of silk fibre increases with increase in extension rate. A fall in tenacity is noticed as the gauge length increases. Tenacity increases as the gauge length of silk filament increases (Ghosh *et al*., 2007).

Tenacity of a silk fibre depends a lot on the silkworm types that produce it. The tensile strength, breaking elongation and breaking energy (toughness) of silk thread from mulberry silkworm cocoons are very much superior to other natural fibres (Shao and Vollrath, 2002). Mulberry silk is more elastic than silk spun by Anaphe species (Thaumetepoidae) with a similar breaking tenacity and less elastic than silk spun by *Saturniidae* species with a higher breaking tenacity.

Tasar silk possesses higher tensile strength and breaking elongation compared to mulberry silk. Tasar silk is more resistant to acids and alkalis, less soluble in concentrated solutions of salts like $ZnCl_2$, $CaCl_2$, LiCl and cuprammonium solution and more resistant to the action of oxidizing agents (Sadov *et al*., 1978). Tasar silk has a lower breaking tenacity than silk spun by mulberry silkworm, but it is much more flexible. In fact, the mechanical properties of silk spun by *Antheraea* species are more similar to silk produced by the spider *Nephila madagascariensis* than they are to silk produced by mulberry silkworm (Komatsu, 1994). These differences probably reflect the different molecular organization and composition of silk spun by *B. mori* and

Antheraea species. The primary protein chain making up silk spun by *Antheraea* species is a poly-alanine chain followed by variable regions of amino acid sequence (Sezutsu and Yukuhiro, 2000). The dragline silk spun by *Nephila* species is also polyalanine with similar nonpolyaline regions as are found in *Antheraea* species. Thus, silk spun by both *Nephila* and *Antheraea* species are organized into polyalanine and non-polyalanine regions, with collective repeats spread non-randomly across the protein transcripts and with a potential genetic 'hotspot'.

The tensile behavior of *A. assamensis* silk are characterized by a large elongation at break (about 40%) and by the presence of a marked yield point at an extension of about 5%, followed by a region of gradual extensibility. The mechanical properties of *A. assamensis* silk fibres are consistent with those reported for other *Saturniidae* silks. The relatively high degree of extension after the initial resistance to low load has been attributed to unfolding of the long fibroin chains in the amorphous regions (Devi *et al.*, 2011).

Sericin coats the outer filaments of the cocoon more and the filament decreases in diameter from the outer layer to the inner layers of the cocoon (Akai, 2000). As a result, the tenacity increases along the filament length within a cocoon from the outer to the inner layers (Kushal and Murugesh, 2004). The harsher methods of sericin removal can cause fibre degradation and a resultant loss of its tensile strength (Freddi *et al.*, 2003).

Silk is an elastic fibre, but its elasticity varies, as may be expected in a natural fibre. After stretching, gradually it returns to its original size and loses little of its elasticity (Potter and Corbman, 1967). The core filaments of silk are composed of highly organized β-sheet crystalline regions and semi-crystalline regions that are responsible for its elasticity (Altman, 2003). However, the non-mulberry silks contain more amino acid residues with bulky side groups. These enable molecular chains in non-crystalline regions of the fibre structure to slip easily when stretched and show higher elongation at break (Kushal and Murugesh, 2004).

The tensile properties of silk have considerably high standard deviations within same type of silk. This is mainly because of the variation in the diameter of the fibers along their length and between fibers. Since an average fineness (denier) was used to calculate the tensile properties, variations in the diameters of the individual fibers resulted in the large variations in the tensile properties. However, such high variation in tensile properties is not uncommon for natural fibers (Reddy and Yang, 2010).

4.3 The role of Eri culture in the socio-economic development of the Bodo people in Kokrajhar District

Ericulture in helping rural economy

Without much capital and other scope, ericulture provides ample scope for employment and income for the survival of those people. Mali (1982) found that utilization of human labour was more in smaller farms where the attention on each activity was more than the bigger farms. He observed a significant positive relationship between hired labour use and the size of land holding. Also there was an inverse relation between the human labour use and the size of land under cultivation that means the bigger firms are more capital intensive than the smaller one. He concluded that the higher employment potentialities of sericulture were well suited to exploit the abundant human resources in rural India.

Ericulture is a labour oriented activity. Therefore, it acts as remedies to the problem of unemployment and poverty in Assam without which the rural poverty would be more complicated. Benchamin and Jolly (1987) identified ericulture as a profession of “low investment and high output” type of employment and income. Though it has been surviving for a long period of time it is not growing at a faster rate due to the lack of capital of the eri rearers and that of the common weavers that prohibits technological invention and innovation. Moreover, the profit rate is not sufficiently high due to lack of organization of the rearers and weavers and hence their poor bargaining power. Nonetheless, it provides some income to those who cannot generate otherwise without much capital investment and a larger section of the rearers can come out of their acute poverty and sustain. Of course, relatively much more income may be generated if spinning and weaving can be adopted along with rearing activity and also through raising bargaining power with the formation of self-help group or cooperatives.

Ericulture contributes more to the family income of those who adopt weaving in addition to rearing of raw silk. Therefore endi-entrepreneurship is very important from the point of employment and income generation, which increase the contribution of ericulture substantially. Moreover, the poorer, who even cannot take up weaving activities together with rearing are also benefited. In spite of comparatively low total earning from ericulture, percentage of family income earned from ericulture is much more compared to those who have been involved only in weaving. Many of the extreme poorer sections can meet their survival. Of course it is clear that if they could be made more enterprising through the adoption of weaving activities they would be highly benefited. Thousands of families in Assam have been involved in various ericulture activities viz. sowing of seeds, plantation of host plants, maintenance of plants, plucking of leaves from the planted and wildly grown trees, feeding and rearing of silkworm up to cocoon stage, spinning of yarn, weaving of fabrics, marketing of cocoons and cloths etc. (Mali, 1982).

Moreover, ericulture is completely managed by rural women folk. The rural tribal women can help the family by contributing in income generation as well as by supplying protein rich pupae to their children and other family members. Involvement to family income makes the women more empowered and independent in the family as well as in the society. Hence, if they are brought under cooperative or self-help group, then they can adopt weaving on a larger scale and can diversify their output through the arrangement of proper training and that will definitely have diverse impact on the condition of the rural poor masses.

A few studies are also done on different sericulture activities of Assam and other parts of India by Dutta (1983, 1988), Choudhury (1984), Ratnala (1990) and Das (2002) who tried to examine the problems, prospects and economic conditions of sericulture sectors. However, most of them stressed much on mulberry, muga-culture and related cottage industries except Dookie (1984) who gave a special emphasis on the analysis of ericulture and eri-silk industry as a source of income and employment in India.

Dutta (1983) conducted a study which provides a brief note about the silk production and its related aspects in Assam. He made an in depth assessment of the net income generated by a family of silkworm rearers with the help of primary data that may provide an indication of its prospects. But the sample used in his study was very inadequate. Dookia (1984) tried to analyze the position of eri silk industry in Indian economy as a cottage industry and discussed its role in creation of employment and income, especially in the rural economy. Choudhury (1984) also attempted to assess the economic importance of silk by estimating gross and net returns per hectare of land under host plant and per family of silkworm rearers. Dutta (1988) discussed the problems and future prospects of eri, muga and mulberry silk industry in Assam especially in the Sibsagar District.

Role of women in ericulture

Income is the most crucial index for accelerating economic growth and development in any meaningful developmental strategy. In the Indian socio-economic background, income generation adopts great significance for women, especially the rural women. Women constitute more than fifty per cent of the world's population, one third of the labour force and perform nearly two thirds of all working hours. Women's income in a family is of paramount importance for nutritional, economic and educational advancement of the family. Time has brought new interests and responsibilities into a women's life and it is now admitted that women's income is indispensable not only for survival of individual families but for maintenance of wider socio-economic system (Batish and Naurial, 2003).

In fact, women are found to bear twofold burden in the development process, one on the domestic front and the other on the financial front. It is found that women are engaged in various works when other members of the family are adoring rest (Gupta and Gupta, 1987). The continuous increase in prices of daily commodities has also pushed women to income making activities within or outside the home to maintain an economically sound family. It is reported that India is the home to 12.7 crore working women and 90 per cent of them are working in various unorganized sectors (Census of India, 2001). However, the participation of women is mostly found in marginal and casual due to inadequacy of skills, illiteracy, restricted mobility and lack of individual status (Chari, 1983).

Women are also mostly engaged in the unorganized sector (Mehta and Sethi, 1977). They are overwhelmingly concentrated in agro-based/household based activities (where they often serve as unpaid family labour) such as dairying, fisheries, small animal husbandry, handlooms, handicrafts and sericulture. Again, in many countries, even in India, women are often paid two-third or even half of the wages earned by men for the same task (FAO, 1995).

Sericulture being a cottage industry provides ample work for the women in rural areas, while their male counterparts look after agriculture. Its unique nature of work proves to be an ideal activity for women who can engage themselves in this activity in addition to their regular tasks of taking care of family. Moreover, most its operations do not require hard labour, except digging and ploughing (Uma Rani, 1998). Silkworm being delicate has to be handled with care. Thus, the entire process needs skill and patience, which suits women well.

The non-worker members were generally children between the age group of 1-12 years and old people of >55 years of age who are generally non-productive population. The present study has reported that female percentage in performing activities of ericulture was higher than male population. Involvement of more female labours in ericulture was also reported in earlier studies (Tom, 1989; Karanth, 1995 and Gregory, 1997).

Adherence to age-old traditional practices, non-adoption of improved technologies, absence of market infrastructure and supporting linkages in the areas are still the limiting factors which are required to be attended for exploiting the existing potential of Sericulture in Kokrajhar District. Major quantities of cocoons are sold outside due to lack of an adequate marketing system. The rearing of ericulture was generally found to be carried out by individuals in small quantities i.e., 10-20 dfls per crop. The survey also revealed that the rearers were unaware about Male: Female (2:1) for coupling for high productivity and day-wise egg segregation to avoid irregularity and diseases in larvae. The proper sanitation measures like cleaning and disinfection of rearing bed regularly, selection of weak and diseased worms were not practiced. Moreover, the rearers were unable to identifying different diseases and conducted rearing using uncertified dfls, i.e., without assessing the condition of the stock. However, if these entire setbacks could be evaded than there is an immense scope for the flourishing of ericulture as well as silk industries in the area.

Brahma (1998) said that the status of women in the Bodo society is high. They can also enjoy property rights in case if there is no male child in the family. They can enjoy such property event after her marriage. But in some grounds it is witnessed that the Bodo women are facing social problems that show the low status of women in the society.

Brahma (1989) suggested that the status of Bodo women can be understood through different roles they play in the family as well as in the society. Talukdar (2012) also said that due to the suffering of various social, economic and political problems in the society Bodo women are facing low status. There is economic backwardness, educational problems, negligence of women education, superstitious beliefs, and low infrastructural development in the area.

The Bodo women are expert weavers and known as born weaver in Assam. So they can weave all their weaving apparels. A Bodo women who does not know the art of spinning and weaving is regarded as 'auluri' (good for nothing), and neglected by the society. The Bodo women weaves on the simple frame loom (salkhuntha) and produce their own requirement of fabrics in their spare time. Almost each and every Bodo women knows how to weave cloth, rearing of silkworm and spinning of silk. The Bodo women still wear the hand woven traditional 'dokhona' (Bodo female dress), sadri (female dress), 'gamsa' (male dress), bisina si or sima (bed sheet), 'dokhona thaosi' (specially used in the time of marriage for bride) etc. Endle (1975a) reported that one of the chief industries, a very profitable one among the Kacharis, is that the culture of the silkworm known as eri cloth. Again he opines that the loom employed for weaving the eri silk is of very simple construction, and most, it not all, the material needed for the purpose can be provided by the villagers themselves from local resources (Endle, 1975b). He further said, the actual work is always carried out either by the lady of the house, or by one of her grown- up daughters and it is in every way suitable to women workers as it requires very little exertion of physical strength, but only a certain quickness and readiness of eye and hand. The condition under which the industry is carried on is in all respects pleasing and satisfactory. Indeed, Kachari women working placidly and contentedly at the eri loom, singing quietly to her in sheer happiness of heart. In Assam, sericulture is mainly practiced by the Bodo Kacharis. It is associates with their socio-economic and cultural life. Therefore, number of families engaged in sericulture. Every household of the Bodos there is a loom. They produce their clothes how far they have need. Various kinds of clothes they produce. For examples- dokhna (main female dress), jwmgra or jwmbaigra (a kind of sunri), gamsa (main male dress), sima or bisina si (bed sheet), aronai (maflar), fali (a kind of towel), endi si (eri cloth), gandu si (pillow cover) etc. Now, the Bodo women have gone to commercial line also by selling handloom industry. There are so many handloom industry lower Assam. Though these industry a large number of poor Bodo women weaver have got scope to engaged herself and maintain their livelihood also. Most of the Bodo workers are small and marginal farmers, or tiny and household industry mainly in rural area. The nature of their work involved in the sericulture industry such as harvesting of leaves, rearing of silkworm, spinning or reeling of silk yarn and weaving are carried out by the Bodo women. Most of the domestic requirements of cloths are made from the family looms. The cloths woven by them are of highly artistic designs. Marriageable girls weave their own bridal apparels by themselves. Even colours used by them for dyeing yarns are prepared from raw indigo and wild herbs. In earlier times, the raw materials for yielding colours were collected totally from natural plants i.e. from tree leaves, roots and stem of different plants. The

Bodo women produced first powder from leaves of Bhaira (a kind of tree), stem of Jackfruit, from oot of Goma khantho and Mohen (a kind of small tree / herb) for yellow colour, from stem of cherry fruit for brown colour, from leaves of laokhri, Amlai (amlokhi) for black colour, and Mwifrai (pori sak in Ass) for red colour. It should be mentioned that powder of leaves of Bhaira tree was necessary to be used as a first step for dyeing all other colours. There was no use of chemical powder for that. As a process of dyeing, the white thread was kept under water mixed with Bhaira leaves powder for a week or more and after that it should be boiled for a few seconds. After that only it becomes ready for dyeing with other colour. Thus, this process of dyeing colour required time, labour and efficiency of the weavers. But still Bodo women practiced this hard process of dyeing. As such every Bodo family had to practice this sericulture and weaving industry as it had an important role to play in the cultural and economic life (Siiger, 2015).

Problems in sericulture

The Bodos are regarded as pioneers in India in so far as the art of rearing silk extracted from worm, especially the eri variety and spinning and weaving of clothes out of the thread thus extracted. The Bodo women are excellent weavers with magnificent sense of design and colour. But this traditional enterprise also has failed to contribute much to the Bodo economy due to archaic technology, lack of credit and market facilities, the role of middleman, and the overall apathy of the government (Kakoti, 2012).

Assam, one of the seven states of NE India, is a region of immense diversity. For thousands of years, people and communities have met and mingled here and customs and cultures have merged and in the process a composite and rich culture has evolved. Development, or the lack of it, has contributed to the disquiet that characterizes the states of NE, including Assam. The region is marked by low agricultural productivity, poor infrastructure, tenuous communications and low levels of industrial activity (Assam Human Development Report, 2003). There is recognition of the fact that Government should play a special role in promoting development; however the gap is increasing. Bordering six states and two countries, Assam accounts for about 2.4 per cent of the country's geographical area. Its 26.64 million people (2001 Census) are 2.59 per cent of the country's population, and its population density of 340 persons per square kilometer is marginally higher than the average density for the country (324 persons per square kilometer).

A few studies are also available there by Dutta (1983, 1988), Choudhury (1982, 1984), Nagarajan (1994), Shamachary *et al.* (1985), Barthakur (1986), Ratnala *et al.* (1990), Sarkar (1988), Siddique (2000) and Das (2002), who tried to analyze the problems, prospects and economic conditions of sericulture. However, most of them stressed on mulberry or muga culture and related cottage industries except Dookie (1984) and Das (2006), who gave some attention on the analysis of ericulture in India.

Other incomes from ericulture

Tapioca tuber as food

Tewe and Lutaladio (2004) reported that the roots and leaves, which constitute 50% and 6% of the mature tapioca plant, respectively, are the nutritionally valuable parts of tapioca. The biochemical composition of tapioca depends on the specific tissue (root or leaf) and on several factors, such as geographic location, variety, age of the plant and environmental conditions. The nutritional value of tapioca roots is important because they are the main part of the plant consumed in many developing countries.

The tapioca plant is a valuable source of carbohydrate, protein and vitamins. Tapioca root is an energy-dense food. However, these macro and micro-nutrients are not well distributed in the plant. Tapioca roots are rich in carbohydrates but poor in vitamins and protein, while tapioca leaves are an excellent source of protein and vitamins. In sweet tapioca varieties, up to 17% of the root is sucrose with small amounts of dextrose and fructose (Okigbo, 1980 and Charles *et al*., 2005). Tapioca shows very efficient carbohydrate production per hectare. It produces about 250000 calories/hectare/d, which ranks it before maize, rice, sorghum, and wheat (Okigbo, 1980). The lipid content in tapioca roots is relatively low compared to maize and sorghum, but higher than potato and comparable to rice (Hudson and Ogunsua, 1974).The roots contain an abundance of arginine, glutamic acid, and aspartic acid. Roots contain small quantities of sucrose, glucose, fructose, and maltose (Tewe and Lutaladio, 2004). Because some strains of tapioca produce substantial quantities of cyanide, which makes them toxic for humans and animals, processing tapioca into ready-to-eat products is necessary to remove cyanogens and other antinutrients (Montagnac *et al.,* 2009). However, processing reduces tapioca's nutritional value, especially when the peel is removed. In addition to genetically engineering and traditionally breeding crops to contain higher amounts of macronutrients, protein content and energy density of tapioca can be increased through processing. Carotenoid-biofortified tapioca is effective in maintaining vitamin A status in an animal model. Continued efforts to improve its nutritional value are important because tapioca is a staple food for many people in developing countries.

Tapioca varieties with low moisture content is suitable for prolonged root storage (Charles *et al.,* 2005 and Shittu *et al.,* 2007). Moisture is an important parameter in the storage of tapioca flour; very high levels greater than 12% allow for microbial growth and thus low levels are favourable and give relatively longer shelf life.

Bradbury and Holloway (1988) and Buitrago (1990) reported low crude protein content of tapioca varieties. Similarly low fat content was reported in tapioca flour (Charles *et al.,* 2005 and Padonou *et al.,* 2005). Crude fibre was reported lower in sweet tapioca and higher in bitter tapioca (Okigbo, 1980). Carbohydrate in tapioca was reported by Montagnac *et al.* (2009) which highly influence the energy content (Charles *et al.,* 2005). The high energy and carbohydrate values obtained in this study suggest that tapioca could be utilized as a reliable food and energy security crop as proposed by FAO (2008); especially owing to their content of some of the most desirable nutritional compounds like carbohydrate, fat, protein and minerals.

Eri pupa: a delectable dish of NE India

In the NE region, the Ahom community consumes silkworm pupae in the mature stage, whereas other tribes (Galo, Naga, Bodo, Missing, Rabiha, Kachari) prefer these insects in prepupal form (Sarmah, 2011). The most favorable insect life stages utilized by indigenous communities are the caterpillars and pupae of the mulberry silkworm and non-mulberry silkworms (*Lepidoptera*: *Saturniidae*), viz., *A. pernyi*, *A. assamensis*, *Attacus ricini* and *S. ricini* Donovan (Paul and Dey, 2011).

Almost all the tribal people of the southern part of the Brahmaputra valley practices ericulture and the pupae are eaten; this extra source of protein in the human diet provides a major incentive to rear eri silkworm. The tribes in hills and plains include the Kacharis and Meches in the northern part of the valley and the Boros, Garos, Synthengs and the Karbis in the Southern part. Additional tribes listed by Singh and Benchamin (2001) are the Jengi, Katoni, Abor, Mizo, Miri and Rabha. The Districts of North Cachar, Karbi Anglong Hills, Kamrup, Darrrang and Goalpara are the chief eri growing areas, and the later locale being a primary source for red cocoons (Chowdhury, 1982). Another factor may be the fondness towards consumption of pupa. They were found to conduct Ericulture as supplementary avocation primarily for pupa, as a delicacy. Third factor may be the establishment of Cocoon Bank at Udalguri, Assam and Eri Spun Silk Mill at Kokrajhar have immense contribution towards the adaptability and popularization of ericulture amongst farmer of the districts due to its immense market value and product and design diversification.

Doley and Kalita (2011) investigated on edible insects and their role in Socio-economic development of rural communities in Assam. They opined that Insects are common food among the Bodo tribe of Assam of NE India. Many species of edible insects are found abundantly in the regions dominated by the Bodo tribe so this tribe is engaged in entomophagy since time immemorial. Numerous references about their nutritional value are available in a wide range of scientific disciplines (Finke *et al*., 2012). Many studies conducted around the world have shown that they are a rich source of quality proteins (Defoliart, 1989). Many insects are an important source of proteins, carbohydrates and vitamins for humans as well as for domestic animals and they contribute significantly to food security and livelihoods in many developing countries (Vantomme, 2010 and Narzari and Sarmah, 2015).

In the NE region of India, particularly the tribal communities of Manipur, Assam and Nagaland, use silkworms' late instar larvae and pupae, chiefly the eri silkworm and mulberry silkworm as food. For the tribes of this region, the pupa of the eri silkworm is so highly regarded as food delicacy that the cocoon is more or less a byproduct (Sarmah, 2011).

Edible insects such as *Dorylus orientalis, Acheta domestica, Lethocercus indicus, Odontotermes obesus, Apis indica, Vespa orientalis, Hydrochara rickseckeri, Heiroglyphus bannian, Neoconocephalus palustris, P. ricini, A. assamensis* and *B. mori* are consumed in Assam by different ethnic groups (Chowdhury *et al*., 2015).

Other byproduct utilization

By-product utilization hopefully can play a crucial role in the coming years to make the sericulture an economically viable proposition enabling it to withstand competition from other cash crops. The useful utilization of byproducts through indigenously available processing techniques brings additional income from sericulture by cutting down the cost of the silk in addition to the socio-economic upliftment of the rearers. Need for introduction of integrated processing complexes with redesigning of present practices deserves special mention to make the practice more attractive and people to participate enthusiastically due to additional income.

The operation of nutritive values of pupae through methodical dispensation certainly boosts up the ericulture as versatile and sustainable among the commercial crops. The effective byproduct utilization from Indian sericulture industry in general and from ericulture in particular can play a crucial role in making it viable and to withstand the competitive competition.

Their high nutritional values of silkworm pupae with good quantities of proteins, fats, carbohydrates, minerals and vitamins, the chrysalis of ericulture is more important as delicacy than its silk. Unlike other silkworms, eri pupae can be isolated from cocoons without damaging the silk as the cocoons were opened at one end. Further, this processes will facilitates smooth spinning of yarn in addition to the maintenance of cleanliness. Eri pupae is great delicacy and dietary staple for Rabhas, Bodos, Abor, Miri, Kachari, Garos, Khasi, Naga, Adis, Mizos, Syntengs tribals of Tibeto Burman and Indo mongoloid origin of NE India (Chaoba Singh and Suryanarayana, 2003). Tribals consuming the eri pupae for their taste, were unknowingly consuming rich protein food material, which was proved later by scientists (Alok Sahay *et al.*, 1997). In Meghalaya, Karbi Anglong areas of Assam, pupae are dried and smoked in ash and hot coal and in other areas the boiled and semi dried pupae look like blackened pea nuts/ cashew nuts, palatable as peanut shells.

The delicious food (endi) items like fry, pakori/chop and cake etc., can be prepared from pupae and in powder form this will be used in soups and sauce as protein source. Silkworm pupae were eaten by Chinese as food (Roychoudhury and Joshi, 1995) and in Japan cakes are prepared and sold as silkworm pupal cakes due to their high nutritive value (Majumder, 1997). In Hong-Kong, China, Korea and Japan the healthy silkworm larvae are sterilized, vacuum dried and sold as commercial food (Ramakanth and Anantha Raman, 1997). In Africa, the mature larvae of Saturniids used as a garnish in raw, dried and powdered form for human consumption and the dried product of pupae, the peaggie and also the roasted pupae are consumed as food in Western United States. Hence the scope of systematic commercialization of the dietary value of the pupae will boost sericulture in general and ericulture in particular by generating additional income to the rearers.

Pupae contain crude protein (55-60%), total lipids (26%), free amino acids (5-8%) and 100 g of dried eri silkworm pupae can provide 75% daily protein requirement of human individual (Chaoba Singh and Suryanarayana, 2003). The vitamins like pyridoxal, riboflavin, thiamine, ascorbic acid, folic acid and minerals like calcium, iron and phosphorus make the pupae more nutritive (Roychoudhury and Joshi, 1995). In terms of protein, fat, vitamins and calories the eri pupae are equal to meat, but for certain degree of indigestibility. However, the biochemical analysis reveals that the pupae are of highly nutritive value and found better than the protein of soya bean, fish or beef. The exoskeleton of pupae contains large amounts of crunchy chitin, which can supplement cereal diet of rural people. During the months of March and May every year the rearers will harvest pupae from cocoons, boil in the evenings and subsequently put them for drying and the methods will vary at different places. The use of pupae in chocolates, in chilli sauce has vast potential for commercializing the concept.

Other uses

The pupae oil has got wide uses in oleo-chemical, soap and food processing industries. The eri pupae are being used as poultry or fish feed in other States. When used as poultry feed hens improved their egg laying capacity with impact on the colour of the egg yolk (Hisao Aruga, 1994). Pupal fat is good raw material in soap industry, glycerin and cosmetics and fat free pupae used as feed of carps and fish for better yields. Pupal protein is used as raw material for preparing amino acids and flavoured products with high nutritive value and fertilizer can be generated from the pupal excreta (Shiva Prakash, 1988). The n-triacontanol, a plant growth promoter is found in good quantities and being extracted from silkworm and the artificial fibres and membranes are also prepared from proteins of pupae (Majumder, 1997).

Chitin, a component of pupal skin used in different applications like additive to increase the loaf volume in wheat flour bread, in post operational treatments such as conchotomy, deviatomy, polypectomy because of its easy usebility, less hemophase, greater pain relief and fastens healing of wounds (Katti *et al.*, 1996). Chitin found as potent antimicrobial against *Staphylococccus aureus, Klebsiella pneumoniae, Asppergillus niger* etc., anti-fungal against *Trichophyton equinum*, its buffering activity against acids, as food additive to control carcinogenicity of food stuffs. Chitin was also used as Immunoadjuvant (antiviral agent), bacteriostatic agent, fungistatic agent, anti-sordes agent in preventing carcinogenic bacteria from teeth and bio compatible membrane to check bleeding in major surgeries (Katti *et al.*, 1996). Silkworm proteins in the form of Serratio peptidase is used in pharmaceuticals for anti-inflammatory, anti-tumefacient action i.e. inflammation of acute sinusitis, tonsiloctomy, oral surgery, during filling, cleaning and taking out teeth. Serratio peptidase was used as enzyme tablets along with antibiotics in treatments for bronchitis, pulmonary tuberculosis, urinary tract infection and to control postoperative inflammations in orthopedics (Teotia, 1988). Certain proteins of silkworm and pupae used as specialty diets for cardiac and diabetic patients because they are easily digestible and reduces cholesterol and blood sugar by providing additional energy and Shinki Fibroin, the derivative of silkworms is used in protein and amino acid extraction in Japan (Ramakanth and Anantha Raman, 1997).

One of the main objectives of ericulture of the region was production of eri pupae for human diet being rich source of proteins, vitamins and hormones but the diversification and commercial approach was lacking (Chaoba Singh and Suryanarayana, 2003 and Suryanarayana and Chaoba Singh, 2005). Further, the potential of silk pupae oil extraction and related activities is not fully attained and still there is wide scope for exploitation. By increasing the production of eri silk and making the availability of eri pupae in large quantities, the concept of their dietary utilization can be commercialized. The prospect of utility of eri pupae and its oil in other profitable areas will definitely encourage the producers of eri silk to enhance its production, because of the importance of chrysalis as delicacy and silk considered as a byproduct. The pupal skin which is available abundantly in the reeling and grainage sectors as a waste can be utilized as commercial raw material for various industries, including pharmaceuticals (Katti *et al.*, 1996 and Han *et al.*, 2002).

With increasing cost of production in sericulture, there is a need to augment alternative income sources by adding value to bye-products to keep the sector viable. Though attempts have been made to utilize bye-products like silkworm excreta, rearing bed waste, molted skin, host plant shoots, sericin, tasar cocoon peduncle, silkworm pupae, silkworm moths etc., same needs to be exploited on commercial scale. Of these bye-products, utilization of silkworm pupae needs immediate attention in view of its production in huge quantities. Value addition through this important bye-product of sericulture in human nutrition, poultry, piggery, fishery, industry etc., is realised. Outcome of studies conducted in India towards development of package for pupae collection and storage for pupae oil extraction/purification, utilization of silkworm pupae as protein supplement in poultry etc., is also important. Further, in view of spread of eri culture out of NE States, need and potential for utilization of eri silkworm pupae is very much essential. Studies on nutritional status and surface lipid content of pupae/pre-pupae, drying of pupae and extraction/refining of pupae oil besides its physico-chemical properties are required to support the potential for value addition in this sector.

Literature reveals that some studies have been done on the utilization of by-products of silk industry (Raju, 1996 and Sonwalkar, 1998). Silkworm pupae are a by-product of reeling industry and it is estimated that in case of mulberry silkworm, annually 1.5 lakhs tonnes of pupae are produced which is generally waste material. In some parts of India the silkworm pupae are regarded as delicious food for human due to their nutritional values (Roychoudhury and Joshi, 1995). In dry eri pupae, the main constituents of eri pupae are found to be 62% crude protein, 44% soluble protein, 25% total lipid and 5.2% ash content. Ericulture is performed traditionally by the tribal communities of Assam and they rear eri for obtaining silk for clothing and to consume pupae as food item. The different items of cusine that can be prepared out of eri pre-pupae and pupae include fry, Pakori/chop, cake etc. The oil portion of eri pupae can be extracted from dry pupae powder by solvent extraction method. Eri pupae oil can be utilized in food industry as well as the source material for oleo-chemical industries (Choudhury, 2003). Waste silkworm pupae generate vast resources of nutrients for livestock and poultry. Silkworm pupae is one of the unconventional top class proteins (65-75%) and lipid feed which is a waste product of silk industry and is obtainable four times in a year. The effects of silkworm pupae on growth and egg production performance are good. The efficiency by the birds receiving silkworm pupae was better as compared to the control. The cheaper waste silkworm pupae could be an excellent substitute of costly protein concentrate in formulating diets for layers leading to increase profitability. The growth performance, egg production performance and profitability almost linearly increased up to 6% dietary levels (Khatun *et al*., 2005). Ii is also realized that in sericulture industry the most generated waste is pupae which can be utilized as inoculums in the fermenting media to produce protease enzyme through submerged fermentation (Chinya *et al*., 2000).

New Sericultural R&D technologies adopted in Kokrajhar:

Recently, introduction of some advanced machineries for spinning of eri cocoons for facilitating production of finer yarns have paved the way to commercially striking designs and products. There is also commercial importance of blends with other natural silks, wool, cotton, synthetic materials etc. (Somashekar, 2004).

Central Muga Eri Research Training Institute, Lahdoigarh, Jorhat, Assam has developed a high productive eri silkworm breed through hybridization programme named as C2 with higher shell weight and fecundity at its subordinate unit Regional Eri Research Station, Mendipathar (Singha, 2010).