CHAPTER – I

GENERAL INTRODUCTION
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Silk not only refers to Bombyx silk whose insects are reared on mulberry leaves and is a high priced, valuable and delicate textile, called the "Queen of Fibres", but also to Tasar silks where tasar worms are reared on Ain, Oak, Arjun, Ber, Badam, etc. During the last century, the silk industry has greatly contributed to the foreign exchange to India. In the world, silk still offers the economic prosperity (Akai, 1998).

Mulberry silk is quite famous but other wild silks are not very popular, although Chinese tasar (Antheraea pernyi G.M), Indian tasar (Antheraea mylitta D), Eri silk (Samia cynthia ricini Hutt), Muga silk (Antheraea assama Ww) and Tensan (Antheraea yamamai G.M) have long been used for characteristic silk textiles, forming a small segment of the market. It has been observed through research that wild silks possess some physiological significance in activities like controlling cholesterol in human body, antibacterial functions and in UV absorption effect, etc. These newly recognized properties may greatly increase the popularity and utilization of wild silks at global scenario as world is facing the problems related to global warming. The International Society for Wild Silkmoths (ISWSM), Japan has started research work on wild silkmoths and silks. The society is established during 1980 and has used available technology to harness various means of wild silk utilization (Akai, 1998).

Based on porosity and the compactness wild cocoon filaments are classified into two types. The former has a porous structure in the cross-section of the filament, containing multiple sizes of fine tubules. The porous cocoon filament is characteristics of species of Saturniidae which includes A. yamamai, A. pernyi, A. assama, A. mylitta, S.c ricini and Attacus atlas L. The non-porous filament of cocoons is feature of all other families viz., Bombycidae, Lasiocampidae, Thaumetopoeidae, and Psychidae families. Bombyx mori Linnaeus, B. mandarina Moore, Gonometia postica Walkar, Anaphe panda Bosid and CRYPTOHELEA FORMOSICOLA Strand, are very famous insects for
this kind of silk from above families. Daba and Sukinda silkworms \textit{A.mylitta} produce the thick cocoon filaments with porous structure which is suitable for fashionable clothing like, sportswear. According to Akai (1998) porous filament maintains a constant temperature and humidity in a textile more than a compact filament. At the smallest class of porous filament, those of \textit{Cricula trifenestrata} Helfer create a fine and soft fabric suggestive of cashmere.

The domesticated \textit{Bombyx} silk has properties which affect cholesterol in human body, alcohol metabolism, senile dementia and diabetes. In wild silks produced under environmental conditions, these factors are expected to be present even more strongly than in Bombyx silk (Akai, 1998). The antibacterial functions of \textit{A. pernyi} and Eri silk are higher than that of \textit{B. mori}. Similarly, the reduction of UV by \textit{A. pernyi} is also superior.

The wild silks possess health related characteristics. Products made from these silks are popularized for these special qualities. Such added values of wild silks will stimulate their increased utilization at national and international level. Very recently, wild silk powder has been obtained (Akai, 1998). This powder too is expected to have health benefits and increase the demand for wild silks (Akai, 1998).

Until ten years ago, wild silk was related to only five species viz, \textit{A. yamamai}, \textit{A. pernyi}, \textit{A. mylitta}, \textit{A. assama} and \textit{S. ricini} in the market. However, in recent years a few other wild silkmoth species have also came to front, \textit{A. atlas}, \textit{C. trifenestrata}, \textit{A. panda} etc. but, there are yet no farms for these silkmoths and only cocoons collected from the field or hills are used(Akai, 1998). \textit{Gonometa} and \textit{Borocera} from family Lasiocampidae are also yielding interesting silks and have unique compact filaments. Establishment of the farms for these wild silkmoths is essential to introduce planned silk production in India. In the present work, \textit{A. atlas}, \textit{A. selene} and \textit{A. mylitta kolhapurensis} sub sp. nov have been tried for their rearing. The work will add great relevance to wild silk industry.

In India (Fig-1), Non-mulberry sericulture is an age old tradition, practiced mainly by the tribal people. When they do not have any work in
agriculture and other allied pursuits non mulberry sericulture provides them moderate earnings in different lean seasons of the year. Wild sericulture remained obscure as an exclusive craft of tribal and hill folks inhabiting the forests of central India, Sub-Himalayan region and north-eastern India for long time. However, in recent years, this traditional craft of tribal has gained tremendous importance. Due to its rich production potential, eco-friendly nature of the activities and steady demand for hand made textile products within and outside the country, wild sericulture is commercially exploitated from traditional craft into an industry of high potential. As a industry it has an advantage of rich natural resources like food plants and tribal manpower. Utilising them to bring a balanced development without disturbing the existing ecological system is the great socioeconomic challenge in sericulture (Shetty and Samson, 1998).

India is the only country bestowed by nature to produce all the three varieties of non-mulberry silks namely tropical tasar, oak tasar, eri and muga. Of the total raw silk production of 14035 MT during the years, 1997-98, the share of non-mulberry silk was only 2.3%. From non-mulberry production, eri, tasar and muga silks account for 69.78%, 24.85% and 5.37%, respectively (Shetty and Samson, 1998).

Host food plants for wild silkworms is crucial factor for wild silk industry. There is practically no systematic plantation of food plants for rearing non-mulberry silkworms in India. Therefore, Tasar silkworms are reared on food plants available in the forest. Muga silkworm rearings is conducted on food plants in forests/village grazing reserves etc and eri silkworm rearing is largely conducted indoors with the leaves of caster (Ricinus communis L) collected from nature grown trees. Recently, the research institutes of Central Silk Board (CSB) have introduced the concept of systematic plantation of food plants for all non-mulberry silkworms to improve the productivity of silks in India (Shetty and Samson, 1998).

According to Sathe & Jadhav (2001) tasar silkworm rearing is practiced mainly in the Central and Southern Plateau region in the humid and dense
forest area covering Bihar, Madhya Pradesh, Orissa and West Bengal, extending to the fringes of Uttar Pradesh, Andhra Pradesh and Maharashtra (Fig-1). It is estimated that in India, there is 11.168 million ha of forest having different primary and secondary food plants for wild silkworms being utilised for tasar silkworm rearing. However, deep interior forests remained unexploited. In India, about 1.40 lakh tribal families have been engaged in tasar silkworm rearing and get benefited socioeconomically.

During 1981 and 1986 with the financial assistance from Swiss Development Co-operation in eight tasar producing states, the CSB has implemented the Inter State Tasar Project (ISTP), under this project, 7845 ha of *Terminalia arjuna* W&A block plantation has been developed with necessary infrastructural facilities required and for overall development of tasar silk industry. Under ISTP Project, efforts have been made by Rajasthan Government for involvement of Rajasthan Vidyapeet Kul, an NGO to take up tasar culture by utilising the plantation and other Infrastructure facilities (Shetty and Samson, 1998).

Eri sericulture is practiced as an indoor activity. Eri silkworms are multivoltine and reared almost throughout the year. The ericulture has a close link with the culture and tradition of the people of north-east. Rural people are involved, primarily to meet the domestic demand of warm clothing and the edible pupae as a major source of proteins. The culture is also marginally practiced in West Bengal, Bihar and Orissa, primarily for production of castor seed and its oil. In general, eri culture is considered a subsidiary source of income for meeting the domestic needs of warm clothing and pupa. The rearers can produce their own seed and conduct rearing, spinning and weaving. The pupal dish of insect diet is sold in weekly market in eastern parts of India. Similarly, the surplus quantity of Eri cut cocoons are sold openly at their door steps (Shetty and Samson, 1998).

Muga, the golden yellow silk produced by muga silkworm is unique to Assam and neighboring states of North-eastern region is also practiced in West Bengal in recent years. Muga silkworm is multivoltine in nature with six
crops a year, two each of commercial, pre-seed and seed crops. Muga silkworm is semi-domesticated and rearable in the open on trees where as spinning arid seed production are indoor activities. In 3,500 ha of land muga food plants are cultivated in North-eastern region of India including West Bengal (Shetty and Samson, 1998).

The drawbacks of non-mulberry sector are poor performance of seed multiplication facilities and non-availability of adequate disease free commercial seeds. There is a great need to manage seed multiplications, the Government sector for quality seed and its timely supply to the rearers in India (Shetty and Samson, 1998).

Recently, a four-tier seed multiplication system is established in India. The Central Tasar Research and Training Institute (CTR&TI), Ranchi is supplying the nucleus seed to Central Tasar Silkworm Seed Station, Lakha which multiplies the same for one generation and supplies to Basic Seed Multiplication and Training Centre (BMSTCs) for further multiplication. They in turn, multiply for one generation and supply the basic seed to Pilot Production Centre (PPC) of the state government. Each BSMTC produces 40,000 dfls and supply is 32000 dfls to eight PPCs @ 4000 dfls per PPC. Eight PPCs in turn produces 3.2 lakh dfls covering 3200 rearers @ 100 dfls per rearer.

In north-eastern and north-western states of India, Oak tasar culture has got good potential where abundant oak flora is available. However, paucity of silkworm seed and lack of adequate extension support system are the main constraints for oak tasar development in this region. Therefore, a major emphasis should be given to this important basic need to ensure production and supply of quality basic silkworm seed in sufficient quantity to enhance the oak tasar silk production. CSB has established three Research Extension Centres in order to fulfill the seed and extension requirements. These refer to REC in Assam, Nagaland and Manipur. CSB has also established the Regional Tasar Research Station (RTRS), at Bhimtal (UP) and RECs at Palampur (HP) in North-western region and these units produce and
supply dfls to 35 seed farms in state sector for enhancing sericultural activities (Shetty and Samson, 1998).

In India, all wild silkmoths i.e. *A. mylitta*, *A. assama*, *S.c ricini*, *C. trifenestrata*, *A. selene*, *A. atlas*, etc. and many more related wild silkmoths distributed in diverse eco-climatic zones. Similarly, considering the ecological conditions, food plant distribution, presence of eco-types and species of diverse nature is in coexistence. It is speculated that North-eastern India is a possible home of origin of species of *Antheraea* from where radiation would have occurred (Nagaraju and Reddy, 1998).

*A. assama* is supposed to be an ancestral species from which other species would have possibly originated. There are number of reasons to accept this concept. There are a few pointers to the hypothetical evolutionary course, all starting from the unique habitat, North-eastern India, one leading to Central and South India represented by the species of *A. mylitta*. The second leading to the North-West along sub-Himalayan belt represented by *A. roylei*, the third leading to Southern China and Japan represented by *A. pernyi* and *A. yamamai*, respectively and the fourth leading to Indo-Australian region represented by a number of tropical species (Nagaraju and Reddy, 1998). The only isolated case is that of *A. polypherous* distributed in USA. However, recent reports (Sathe, 2007) indicated that at least 13 species of wild silkmoths exists in Western Ghats of Maharashtra due to availability of rich flora of the region.

The Saturniid silkmoths have variations in chromosome number from \( n = 15 \) to \( n = 49 \) with an average chromosome number of the family \( n = 31 \). Rare cases of interspecific hybrids of *Antheraea* shows diverse chromosome number of \( n = 31 \) and \( n = 49 \) are known to yield fertile and vigorous hybrids. According to Jolly et al., (1969) the interspecific hybrids generated using many other *Antheraea* species uncover interesting genetic relationships of the species involved. The holocentric nature of the chromosomes, presence of supernumerary
chromosomes and chromosome numerical polymorphism in the species of *A. roylei* and fertility of the F₁ interspecific hybrids of *A. pernyi* and *A. roylei* despite trivalent formation show that the chromosomal fission has probably played central role in the evolution of Saturniid silk moths, (Puttaraju and Nagaraju, 1988).

Except *A. yamamai* in all the *Antheraea* moths where eggs undergo hibernation, the diapause sets in at pupal stage. Many species and eco-types have high degree of plasticity to shift from uni/bivoltinism, trivoltinism depending on the photoperiod during larval stage and nutrition (Nagaraju and Reddy, 1998).

The biotechnological approaches such as recombinant DNA technologies, immunological methods, protoplast culture, hybridoma technology and gene transfer methods have provided solutions to many problems to conventional approaches in sericulture. The vast genetic resources from non-mulberry silk moths offer, the influence of many of these recent developments for expecting new rearable varities of wild silkmoths. In fact, the active research that is going on mulberry silkworm *B. mori* as a model genetic system has already provided important insights into the fundamental biological process would worth implementing against wild silkmoths at global scenario (Puttaraju and Nagaraju, 1988).

*A. mylitta* as a polyphagous worm has fairly wide area of distribution in tropical belt extending from 16 to 24° N and 80 to 88° E covering both deciduous and semideciduous forests. It has 44 ecoraces distributed in India. The ecoraces such as Daba, Laria, Modal, Sukinda, Bhandara, Raily, Nalia, Sariban and Andhra local are considered important from the commercial view point. These ecotypes differ sharply in their characteristics and offer rich genetic repertoire in terms of their qualitative and quantitative economic characters. Unfortunately, systematic use of these eco-types is yet to be establish in tasar culture. Their
diversity in voltinism, food plant preference and hybrid vigour manifestation has great practical potential value. The above study needs basic understanding of the genetic architecture of eco-types, which would throw light on their uniqueness, genetic distances and genetic variability. Such information could be profitably used to identify the eco-types which give optimum level of heterosis in the hybrids, to preserve the genetic identity of the eco-types and to evolve breeding strategy for maintenance of genetic diversity (Puttaraju and Nagaraju, 1988).

Ecoraces have not studied with line of worth while economic interest. There is pronounced phenotypic and behavioral plasticity between ecoraces which would worth establishing their rearing relationships. The breeding programmes related to different eco-types conducted earlier could not succeed to the desired level. The reasons for such failures might be absence of well defined genetic markers. The breeding plans fail to reach the desired levels due to the fact of absence of genetic identity and genetic distance of the parents. Therefore, Tasar culture still waits for ways and means for rational characterization and utilization of eco-types to arrive at high yielding, disease resistant and amenable hybrid combinations of silkworms. Recent developments, in the field of molecular biology there are several recently introduced molecular marker technologies such as random amplified polymorphic DNA, inter-simple sequence repeat polymorphisms, simple sequence repeats based polymerase chain reaction, restriction fragment length polymorphisms etc. Such techniques are being intensively used in crop and animal genetics for protection of breeders' rights, conservation of genetic diversity, incorporation of desired traits through molecular marker assisted selection, germplasm characterization, genome mapping and map based cloning (Shi et al., 1995; Nagaraja and Nagaraju, 1995; Nagaraju et al., 1995).

The fertile interspecific hybridization is a rare phenomenon in insects. Genetic analyses of such fertile interspecific hybrids throw light on the
phylogenetic relationships of the wild silkworm species. Jolly et al., (1969) reported the cases of fully and partially fertile interspecific hybrids in the genus *Antheraea*. Nagaraju and Jolly (1986) studied the species of *A. pernyi* (Chinese oak silk moth) (*n* = 49) and *A. roylei* (Indian silk moth) (*n* = 30, 31), followed by the studies of (Kobayashi and Tanaka, 1988; Shimada and Kobayashi, 1992) involving *A. yamamai* (*n* = 31) and *A. pernyi* (*n* = 49). The hybrids have quite interesting features in one full and the other partial fertile interspecific. The interspecific hybrid involving *A. pernyi* (*n* = 49) and *A. roylei* (*n* = 31) produces fully fertile F1 hybrids and could be inbred and backcrossed as well to *A. pernyi*. The chromosome pairing pattern in the fertile F1 hybrid revealed 18 trivalent and 13 bivalents. Wherein stabilized chromosome number of *n* = 49 in the interspecific hybrid population inbred was found for 49 generations. It is very likely that the chromosomes which involved in trivalent formation were gradually excluded during in breeding and only those zygotic combinations which contain bivalents would have been retained in the population. Thus, the present day inbred hybrid of *A. pernyi* x *A. roylei*, referred to as *A. proylei* has only *n* = 49 (Nagaraju, 1998). However, the fact is unknown as to what extent the parental genomes are represented in the stabilized inbred populations of *A. pernyi* and *A. roylei* (*A. proylei*). According to some workers many silk yield attributes and the vigour have substantially declined in the present inbred populations of *A. proylei*. The molecular genetic analysis of the interspecific hybrid and descendant populations, using DNA markers and chromosome painting, probes could explain the status of *A. roylei* chromosomes, which involved in the trivalents during the course of interbreeding of the hybrid.

The work on retaining and breeding a large number of inbred derivatives from backcross and F2 populations of the interspecific hybrid, which are likely to carry a different of chromosomal complements to track the parental
chromosome, by using mapped DNA markers and chromosome painting probes have great importance in wild sericulture development.

According to Kobayashi et al., (1982) there are conflicting observations with regard to the fertile nature of the *A. yamamai* and *A. pernyi* interspecific hybrids. Shimada and Kobayashi (1992) have not been able to advance the interspecific hybrid beyond F₁ generation. But, Kobayashi et al., (1982) have advanced the interspecific hybrid to F₂ generation. Shimada and Kobayashi (1992) have successfully obtained progenies from the backcross of F₁ male (*A. yamamai* female X *A. pernyi* male) X female of *A yamamai*. Such success opens up the possibilities of raising new breeds that combine the high quality silk of *A yamamai* and bivoltinism of *A pernyi*.

Biotechnological advances have made it possible to express foreign genes in heterologous organisms. The main goal of such work should be to develop methods for efficient production of a large amount of purified, biologically active proteins to study the basic mechanism of gene expression and the biological effects of products in cells and organisms and their possible pharmaceutical use. Baculo viruses are extremely useful vectors in for their successful expression of biologically active proteins. For expressing proteins of biomedical importance, a good progress have been made in *B. mori* nuclear polyhedrosis virus (BmNpV). Zhang et al., (1992) developed the recombinant expression vector of *A. pernyi* nuclear polyhedrosis virus (ApNPV) successfully and used for the expression of DE protein in *A. pernyi* pupae. *A. pernyi* can be considered as an ideal host to express the foreign proteins using ApNPV due to its advantages such as pupal diapause when pupa sleeps for several months, its sensitivity to infection and cheap cost of production.

Insects are capable of detecting foreign cells and foreign molecules of eliciting effective and specific defensive response in response to invasion of foreign bodies. Among the components of immune response, wound healing and
haemocytes and synthesis of a battery of defense proteins have been investigated. The synthesis of bacteria elicited proteins has been reported in *A. pernyi* (Qu et al., 1982), *Philosamia cynthia* D (Boman and Hultmark, 1987) and *A. mylitta* (Nagaraju et al., 1992). But, the novel antibacterial proteins, their regulation of expression and their precise role in immune response in Saturniid silk moths is to be detected in near future.

Silk proteins, particularly, fibroin, small fibroin, and P25 which constitute actual silk fibre are produced only in the posterior silk gland and sericin protein which cements the silk fibre is produced only in the middle silk gland in a highly tissue specific manner is demonstrated in *B. mori* (Nagaraju and Reddy, 1998). The genes coding for all these proteins have been cloned and characterized. However, *Bombyx* and *yamamai* fibroin genes are quite different in their structure but their regulatory regions are conserved.

According to Kundu (Personal communication) in *A. mylitta* and Syed (personal communication) in *A. assama* the amino acid sequence and composition in these species are quite different from *Bombyx*. Silkmoths are holometabolous insects and they manifest robust circadian behaviours that involve in the timing of the photoperiodic termination of pupal diapause, adult eclosion and egg hatching behaviour (Puttaraju and Nagaraju, 1988).

The discovery of period gene that codes for period protein revealed that period gene expresses early in four cells of each of brain hemispher, with one lateral pair and one medial pair in the dorsolateral region (Sauman and Rappert, 1996). The period gene has important role in the circadian system. Extension of such studies to Saturniid silk moths on circadian behavioural pattern would be helpful for managing wild silk in better way in sericulture business.

Wild silkworms exhibit well defined taxonomical diversity. There biodiversity is well known in all aspects of their life from egg to moth. Diversity in food habit and physiological constitution has been illustrated in *A. mylitta*
Indian tasar) *A. pernyi* (Oak tasar), *A. roylei* (Wild oak tasar), *A. Assama* (Muga), *Attacus synthia* (Wild eri) and *A. ricini* exhibit.

The tasar silkworm *A. mylitta* in Central India is being fed on Sal *Shorea robusta* Roxb and its "Daba" variety in northern Bihar (India) feeds on Asan *Terminalia tomentosa* W&A and *T. arjuna*. Attempts to rear raily, the ecorace of tasar on *T. tomentosa* and *T. arjuna* resulted in high mortality with poor specimens of cocoons. While, Sal based raily are characterized by black coloured short peduncle and deep brownish grey to blackish cocoons. They are hard as stones, rich in silk content and the silk thread is thick with high denier. The raily silkworms are predominantly green with or without lateral shining spots. They camouflage perfectly with the back ground of Sal leaves. The race goes in diapause in pupal stage and complete one life cycle in a year showing univoltinism. The male moths are dark brown to deep brick red colour and females are deep yellow to brownish grey. Males have wings well adopted for long flights before mating. The eggs are different from Daba variety by a specific follicular imprint (Narasimhanna, 1998).

The primary food plants of Daba ecorace, *T. tomentosa* and *T. arjuna* are grown in Southern Bihar and bordering Orissa state. However, rearing these silkworms on Sal is not successful. Daba tasar silkworms are adopted to the warmer and humid climate of June -July-August as a seed crop while, without diapause, second generation is adapted to less humid and comparatively favorable cooler seasons of September-October-November as commercial crop exhibiting bivoltinism. However, seed crop is poor in structure and silk content, the 2nd crop yields hard cocoons with rich silk content. In November - December the pupae of 2nd crop undergo diapause and emerge as moths in July next year.

According to Narasimhanna (1998) the Daba ecorace has shown tremendous potentiality to adopt and survive adverse and favorable climatic factors with the ecosystem unlike the univoltine raily, Berharva and Bhandara
The egg structure, larval pattern and moth characters are morphologically different in Daba than that of raily. The larvae also show following differences that they exhibit fast colours - green, yellow, blue and whitish with adoptability for camouflage in the new environment for protection of itself from different types of predators. The peduncle of Daba cocoon is longer than raily with dark-brownish to yellowish coloured cocoons. Sal based cocoons are darker in shade. Daba cocoons are comparatively easy to rear and the silk produced is of thinner denier than that of raily. Moths are lighter coloured in Daba than those of raily, Bhandara and Berharva ecoraces. Daba moths are vulnerable to breeding in captivity unlike their counterpart of central India.

A. mylitta can also shows biodiversity in the form of Sarihan ecorace of eastern part of Bihar, Bogai ecorace of Orissa, Laria ecorace of southern Bihar (Ranchi) and Andhra ecorace of Adilabad in Andhra Pradesh. In all these ecoraces, three generations are completed in a single year. During the first two generations, they struggle for existence in adverse conditions and only those which are fit, survive to produce commercial cocoons during favourable seasons. Andhra ecorace is adopted to T. tomentosa which is available as shrub unlike the big trees of South Bihar where Daba ecorace is grown. The larvae are characterized by having smaller in size and green colouration mostly. But, occurrence of four colours green, yellow, blue and white is reposed in Sarihan, probably due to adoption to a particular eco factor. Nature of cocoons produced are also different.

Laria ecorace is characterized by a long peduncle and yellow cocoon, while the cocoons of Bogai and Sarihan ecoraces are small in size with deep brown to black peduncles. However, moths are smaller in size than Daba ecorace with predominantly brick red males and yellow and greyish Females. The tasar silkworm A. mylitta thus, shows biodiversity in morphological, physiological and economic features. Sal based raily ecorace is univoltine. Daba is bivoltine and
Sarihan is trivoltine. Daba and Sarihan are adopted themselves to the variable seasonal climatic conditions of ecological areas. Interbreeds between these races have been tried but, the attempts were not so successful for commercial exploitation leading to a question whether the status of such species can be confirmed or ecoraces to be retained for these tasar silkworms of different regions (Narasimhanna, 1998).

Attempts have been made in the crossbreed of *A. pernyi* and *A. roylei*. The above species feed on oak plants. *A. roylei* is wild and *A. pernyi* is a cultivated species. *A. pernyi* produces fine reelable, shining silk and the cocoons of *A. roylei* can not be reeled or spun, there by of little economic importance to that of *B. mori* and *A. yamamai*. In north and north eastern parts of India *A. pernyi* is commercially exploited for its silk as it is well adopted to colder and warmer eco systems with their monocycle and bicycle life style. *A. pernyi* produces brownish cocoons with thin peduncle and single layered, while cocoons of *A. roylei* are greenish with two layered and multi cornered outer shell. The larvae also differ morphologically. Similarly, the moths are also different as reddish brown in *A. pernyi* and greenish grey in *A. roylei*. Their hybrids are also viable (Narasimhanna, 1998).

The Japanese tasar silkworm *A. yamamai* is confined to central Japan. Silk of *A. yamamai* is characterized by lustrous cocoons with fine denier, making it a most sought silk specially for embroidery. The silk *A. yamamai* is having great demand.

Muga silkworm, *A. assama* is confined to Brahmaputra valley of Assam, in India which feed on Som and Soalu plants. *A. pernyi* and *A. mylitta* can also feed on above plants. The seeds of this species are available for rearers and is commercial cocoon crop. However, the mortality of larvae is high in seed crop leading to shortage of eggs for commercial purpose. Thus, it is belived that the species is ill adopted to the seed cocoon season.
The tasar silkworms continue to feed on the leaves of host trees, but, *A. assama* larvae crawl down after the leaves are consumed. Those worms are picked and transferred to other plants. Mature larvae also crawl down which are picked and put to baskets containing leaves for spinning cocoons. This is unique habit of the silkworm found in *A. assama* which is not seen in any of the wild silkworms. The cocoons of *A. assama* are compact, single layered and without peduncle. The brownish coloured cocoons can be reeled on special contravences. The silk is brilliantly lustrous brownish in colour. The species exhibits uni, bi and trivoltinism in wild state. No brilliant colours are seen in the moths as seen in *A. mylitta*. Thus, the moths are dull reddish brown coloured in *A. assama* (Narasimhanna, 1998).

Next to mulberry silkworm *Bombyx mori* L., Eri silkworm *Attacus ricini* Bosid and *A. cynthia* Clement is the only wild silkworm reared indoors. Their regular host plant is castor (*R. communis*) but, occasionally they are reared on Kesseru (*Heteropanax fragrans* Seem) leaves. These worms are well adapted to high humid ecofactors of Assam region. The hardy larvae exhibit green, blue, yellow and white colours like those of *A. mylitta* with difference in tubercle structure. *A. ricini* spin white coloured soft cocoons while, the wild *A. cynthia* spin brick red coloured soft cocoons. The cocoon structure of these is different from any other wild silkworms. However, the cocoons of *A. mylitta* are hard, with thick peduncle, and those of *A. pernyi* are comparatively soft and thin peduncled. In *A. ricini* the outer layer of cocoon is hairy, soft and the inner layer is comparatively harder. These cocoons are entirely different from the cocoons of *A. roylei* wherein outer layer is harder and inner layer softer. The moths are black in colour and do not exhibit bright colours of *A. mylitta*. The cocoons are soft and not reelable because of the ununiform of fibre. They are fit only for spinning. The silk of *A. ricini* poor quality and lacks luster. The rearing of this species is more
related to human diet (pupae are eaten by Tribals) than for the silk. These Cocoons are sold after removal of pupae or after emergence of moths. Eggs are produced indoors and are laid on Khorikas (Narasimhanna, 1998).

Biodiversity within a species like tasar reveals its potentiality and the genetic adaptability through interaction with environment, to struggle, survive in varying ecological nitches. Biodiversity is a way of life in wild silkworms and well adopting to the living conditions in adverse ecological situations for yielding valuable silk for mankind.

The availability of food plants for non-mulberry silkworms has tremendous importance in enhancement of the non mulberry silks. Therefore, making the index of non mulberry silkworms and their host plants is crucial task in wild sericulture. The tropical tasar have been endowed by nature with vast forests food plants but, temperate tasar have different species of *Quercus* distributed throughout the temperate zone of north hemisphere and extended up to the tropics and subtropics of India, as food plants. For muga silkworm (*A. assamensis*), Som (*Machilus bombycina* King) and Soalu (*Litsea polyantha* Juss) are the two principal food plants. For eri silkworm Castor (*R. communis*), is main food plants and Kesseru (*Heteropanax fragrans* Seem) and Tapioca (*Manihot utilissima* Pohl), are secondary food plants. However, the non-mulberry food plants are not available in organized form. The tropical tasar food plants *T. arjuna* (Arjuna) , *T. tomentosa* (Asan), Oak, Som and Soalu are the forest plants while Castor, Kesseru and Tapioca plants of eri silkworms are found often in the gardens/backyards of farmers, due to their manifold uses (Sinha 1998). Therefore, from sericulture point of view, a large population of food plants is required in an organized form which may be cared suitably to provide quality leaves for silkworm feeding. Naturally, they are well distributed in different states of the country and occupy 25% area of the total forest cover. In states of Madhya Pradesh, Bihar and Orissa, the wild silkworm food plants are widely
distributed. Some tasar food plants do exist in the villages on bunds of fields which farmers primarily use as shade trees can be managed for sericulture purpose.

The Western-Himalayan range at 1200 mtrs and in the eastern hilly tracts which constituting a major part of the forest are good areas for different species of oak in India. Traditionally, muga culture is practiced on irregularly scattered nature grown tall trees along the sub-himalayan hill ranges, particularly in the North-eastern India.

Regular cultivation of castor is done for oil seed and other purposes than sericulture in North-eastern states including Assam, the homeland of ericulture. Same is true with tapioca in Southern states are potential areas of ericulture in India. However, ericulture is now recommended by CSB for almost every states of India because, where caster is grown, ericulture is possible.

The ever increasing urbanization and lopping of forest have led to gene erosion of many valuable genotypes of various species of non-mulberry flora (Sinha, 1998a). Therefore, suitable strategies for conservation of genes and genotypes of these sericultural flora and fauna to maintain bio-diversity and to continue the age-old tradition of non-mulberry sericulture required even at high premium. According to New Forest Policy (1952) the area under forests should be to 33.3% of the country’s total land area. Government of India adopted this resolution. The forests which have protective role in balancing the environment have been depleting in great proportion. Even the tribals are also adopted for lopping of forest trees for their livelihood. In the absence of any alternative forest based employment, forest is bound to shrink at a faster rate (Sinha,1998a). Non-mulberry sericulture is one of the most important alternative means of livelihood of 10% tribal population of India. Therefore, wild sericulture can save forests and simultaneously improve the socio-economic status of tribals and helps to promote suitable use of forest and safeguards their genetic resources. Soil erosion
and several environmentally problems are related to wild sericulture. Wild sericulture thus, adds great relevance in solving environmental problems.

According to Khosla (1988) the concept of genetic conservation has developed with rapidly narrowing genetic base of traditional varieties. Though a large number of proposals for conserving gene resources in forest trees have been made, only a few of them are being practiced for non mulberry food plants. There are basically two types of conservation strategies viz, *in situ* conservation in natural strands and *ex situ* conservation both in living conditions and storage banks.

So far, no genetic resources of non-mulberry food plants have been established, hence attempts should be made in this direction in every state for their inhabitant species by the concerned forest department or sericulture department. Seed strands or seed production areas should be established in different states which can serve as control or check lots. Tree selection is also one of the methods to conserve the maximum diversity at species level and can be preserved through cloning. Attempts for cloning in most of the non mulberry food plants have been made but with some limitations propagation through cloning of perennial food plants of eri are yet to be established.

Knowledge of breeding system, biology and biological characters of the species is the pre-requisite for *ex situ* conservation the *ex situ* conservation is expensive to establish and maintain and therefore, they are confined to species of proven potential value. Seed orchards of non-mulberry food plants should be established primarily for the production of seeds of genetically proven quality. There are two types of seed orchards, clonal and seedling. They can be used as germplasm material for mass multiplication by vegetative means. The non-mulberry food plants parts viz, seed, fruit, pollen and tissue should be exploited on large scale in *ex situ* conservation of germplasm of flora of wild sericulture (Sinha,1998).
The tasar culture is largely confined to the forests due to the existence of a fairly large amount of forest flora to required for the culture. There is a need to systematic plantation of good varities of non mulberry food plants due to lack of systematic plantation in North-eastern India has restricted the muga culture to a limited pocket only and same is the case of eri culture. Through abundant flora is available, in the region, non-mulberry sector has proved non-productive due to the above reasons.

The tropical tasar of *A. mylitta* which is reared on *T. arjuna* and *T. tomentosa*. Though a large quantity of tasar cocoon is collected from Sal (S. robusta) forests, it has never been considered as a dependable food plant of *A. mylitta*, Central Tasar Research and Training Institute (CTR&TI), Ranchi developed widely acclaimed technology for multiplication of these food plants. The ripe and mature seeds are collected during March and April. Then grading is given according to maturity. Seeds are soaked for 196 hrs in case of *T. arjuna* and 48 hrs in *T. tomentosa*. The soaking is done in plain water. The soaked seeds are heaped under tree shade and covered with moist gunny bags. After six days the seeds start germination. The germinated seeds are dibbled on polythene tubes of 25 x 10 cm. size which contain rooting mixture of FYM, soil and sand (3:2:1). Regular watering and care is taken in nursery beds and such seedlings are ready for field transplantation with three months. 30 x 30 x 30 cm size pits are used for transplantation with spacing of 1.25 x 1.25 m in case of *T. arjuna* and at 1.80 x 1.80 m in case of *T. tomentosa*.

**Development in Tropical tasar**: CSB and CSR&TI, Ranchi have developed following strategies for improving tasar sericulture -

1. **Nursery technique for raising Arjun and Asan seedlings** - for raising Arjun (*T. arjuna*) and Asan (*T. tomentosa*) seedlings in a large scale were evolved which ensured uniform and quick seed germination of 85-90% and 60% respectively. The successful raising of seedlings of nature grown Arjun and Asan trees helped
in the implementation of inter State Tasar Project leading to about 8000 ha of Arjun bush plantation in tasar growing states. This is a major step taken towards augmentation of host plant in tasar sector.

(2) **Introduction of scheme of economic plantation** - Economic tasar bush plantation with 4' x 4' spacing was found to be ideal for maximum leaf yield. Therefore, economic plantation one ha land accommodates 6,724 plants and the yield of leaf at the end of 4 years is 18 MT. The technique has been demonstrated to generate interest in the rearers for its adoption.

(3) **Good strategy for pest management of host plants** - A suitable technique has been developed to minimize the damage to host plants from the gall insect (*Trioza fletcheri Minor*), stem borer (*Sphenoptera sps.*), and defoliating insect (*Notolophus sp.*) which are the major pests of tasar food plants. For minimising attack of parasites and predators to tasar silkworm, an integrated pest management strategy has been developed which involved judicious use of chemicals and biological control agents.

(4) **Package to silkworm diseases control strategies** - The Package of practices both for preventive and curative measures against diseases of tasar silkworm *A. mylitta* specially, pebrine, bacteriosis, viruses and mycosis have been suggested. The diseases causes 30-40% loss to sericulture industry. Tasar Keet Oushadh has been formulated to control the bacteriosis, viruses and mycosis.

(5) **Improvement in the rearing techniques** - The controlled rearing technique has been evolved for first stage worms in indoor conditions. Further, to increase yield and quality of the foliage during rearing period, foliage spray of 1.5% urea on *T. arjuna* improved the yield and quality of leaves. At the same time, yield of cocoons per dfi increased to 70-80 cocoons which against previously had 20 to 25 under traditional methods.
(6) **Isolation of trivoltine races** - A stable trivoltine line of Daba and Sukinda races has been isolated successfully which helped in the introduction of third crop rearing with higher ERR.

(7) **Seed preservation technique** - An ideal grainage house with mud wall; thatched or tiled roof of 15' x 20' dimension with 8' all round verandah has been recommended for preservation of one lakh cocoons. The grainage has been designed keeping in view the higher temperature conditions prevailing in tasar producing states, during summer months.

(8) **Improved technologies for silk extraction** - For softening of cocoons and making efficiently reelable, Proteolytic enzymes viz., cocoonase, Biopril-50, Papain, Trypsin and Pepsin have been screened. Raw papaya has been also introduced as a softening agent with least damage of silk quality. While, 100% cooking is ensured by pressure cooking.

(9) **Fabrication of reeling machine** - For producing 400 gm of reeled silk in 8 hr a four spindle reeling machine has been fabricated and demonstrated. Therefore, traditional techniques can be replaced. Further, studies are in progress to reel the pierced/emerged cocoons which are hitherto considered unreelable. It has been observed that the reelings of pierced/emerged cocoons are more profitable than using the ghicha technique. The above improvement in the technology will certainly encourage the wild sericulture in India (Sinha, 1998).

Recently, a technique has been improved to the reeling and spinning of cocoons through sustainable research and technology upgradation programmes by the Central Silk Board. The traditional technique was crude and primitive, for preparation of silk yarn from the wild silk cocoons.

**Reeling of tasar cocoons:**

The cocoons of tasar are hard, they are cooked in water with a pinch of soap and soda for 5-6 hours. The cooked semi-dried cocoons are deflossed by hand to get the filament ends. Five to six cocoon filaments are combined
together, rolled over the thigh and are wound on a bamboo natwa. Traditionally, tasar cocoons are reeled by women. Hence, woman can reel 60-70 cocoons per day, which will produce about 50-60 gm of reeled silk (Ghosh,1998).

The above method is replaced with improved technique of cooking of cocoons with the help of soap and hydrogen peroxide and introducing a power operated reeling machine consisting of four ends. The machine can insert upto 8-9 twist/inch (tpi) with the yield of 150-200 gm of reeled silk/8 hr. After steam setting the yarn produced by the machine can be used for weaving on handloom and powerloom with any further processing. Qualitatively such yam can increase in weaving efficiency and fabric quality and comptitable with Chinese tasar silk (Ghosh,1998).

In India, Non-mulberry sericulture forms an important part of tribal economy, particularly in Eastern and North-eastern states of the country and Maharashtra. It also plays an important role in arresting the deforestation and generating gainful employment to the tribal population. India has abundant manpower and rich natural resources of food plants for wild silkworms. Therefore, there is need to utilise these two resources for the economical development of the country. The tribal population of India is over 40 million and nearly three-fourth is located in tasar producing states. Tasar sericulture is highly beneficial to tribal population since wild silkworm rearing is a low cost technology with practically no investment (Jahagirdar,1998).

In Eri and Muga silk production India ranks first and second to China in Tasar silk. Both tropical & temperate tasar culture are practiced in India. Tropical tasar culture is concentrated mainly in tribal belts in the states of Bihar, West Bengal, Orissa, Madhya Pradesh, Andhra Pradesh, Maharashtra and Uttar Pradesh while, the temperate tasar culture is performed in the hilly regions of Uttar Pradesh, Himachal Pradesh, Jammu & Kashmir and North-eastern states. State wise, Manipur ranks first among the temperate tasar silk producing areas.
Assam alone accounts for over 95% of Muga and over 60% of Eri silk. Average annual production of wild silk is estimated at about 2075 MT comprising 1530 MT of Eri, 428MT of Tasar and 117 MT of Muga silk during the years 2007-2008. In case of Muga and Tasar, annual fluctuations in production are common due to natural vagaries and as an outdoor activity. However, wild silk industry is facing to a number of problems and one of the major problem is lack of adequate market support.

Tribals harvest wild silkworms using forest trees, produce cocoons and sale in weekly haats at any prices offered. The producers are exploited by the commission agents due to monopoly. The traders (known as Mahajans) have links with buyers from other states. By the time, the cocoons get hoarded for long periods. There is another class of small time traders located around production areas who act as go between big traders and local weavers. Their modus operandi is like that of itinerant rural agents. Apart from operating in haat areas directly, these petty traders also buy cocoons from bigger traders cum financiers, supply to local releers or weavers and retain good margin for themselves. The traders have no fixed practices or rules of pricing and hence, they can manage business (Jahagirdar,1998).

However, during last two decades there has been tremendous improvement in the market system for wild silk products that Central Silk Board has provided alternative market support through establishment of two Raw Material Banks, one each for Tasar and Muga. The state governments also introducing regulatory and intervention measures to protect the interests of the tribals and to promote silk industry. Bihar, Orissa, Andhra Pradesh, Maharashtra etc, have established their own agencies for marketing of silk. While, other states like West Bengal and Uttar Pradesh promoted marketing environment without direct participation. This has, resulted in a competitive atmosphere to producers. Now each state has its own policies and priorities on wild silk industry.
In India Tasar silk products in various states are controlled by the Mahajans. There is some kind of traditional and financial link between trader-cum-financiers and producers under which producer have obligations to sale their cocoons only to the Mahajans or their agents whom they are indebted. Therefore, traders/Mahajans purchase cocoons at prices much lower than the prevailing market rates. This arrangement affects the interest of producers.

For dealing with wild silk products and cocoons every state in India has its own arrangement. Three centers have been established, by State Department in Bihar for tasar marketing which purchase tasar cocoons and dispose off the same to the reelers/ weavers and their societies. However, these centers are not fully equipped with facilities and resources to play effectively role in marketing.

In Orissa, tasar cocoons are not permitted to be either sold or purchased by any agency other than the Orissa State Tasar co-operative Society (co-operative federation) which holds monopoly, is unique feature of Orissa state in wild sericulture. The government sponsored co-operative societies procure cocoons through a network of procurement centers in Madhya Pradesh. In Andhra Pradesh, the SERIFED, a federation sponsored by the state government operates through the Department of Sericulture for purchase and disposal of cocoons and yarn. The Development Corporation of Vidharba Ltd. (a state owned multipurpose development body corporate) provides market support to the producers in Maharashtra. While, in West Bengal, the Department of Sericulture procures only seed cocoons and supervises sale/purchase of commercial cocoons which is carried out at its selected centers. In Orissa and some other states, Govt. neither exercise monopoly nor restrict transaction of cocoons and allow market forces to operate. The governments only fix minimum floor price for cocoons (Jahagirdar,1998).

With a view to provide alternative and remunerative market and also to regulate the prices for cocoons, the Central Silk Board set up a Raw Material
Bank (RMB) for Tasar in Chaibasa (Singhum District of Bihar) in 1972. The RMB is operated through its main office at Chaibasa, supported by two sub-depots one each in Raigarh (Madhya Pradesh) and Bhagalpur (Bihar). Initially, the RMB and its units did provide a formidable competition to traders, but over the years, there has been a gradual reduction in their direct market purchases.

Presently, its overall share in the market is not significant. However, the RMB is not in a position to meet the full requirement due to meager supply. The RMB has facilities for long term storage, reeling and spinning as a standby arrangement. The TRIFED (A Government of India sponsored agency) is also engaged in purchase and processing of cocoons/yarn and fabric production. It procures cocoons from RMB and co-operatives operating in respective states. Its annual cocoon and yarn transaction is too small to influence the market. The Khadi and Village Industries Commission and Khadi and Village Industries Board in respective states have promoted co-operative societies which also buy cocoons from producers to some extent (Jahagirdar, 1998).

For ensuring remunerative returns to producers, Price Fixation Committees have been constituted in every state of India. Although, prices are fixed on different criteria, each state follows different norms. In Bihar, which accounts for highest production of tasar silk, the Price Fixation Committee fixes prices for different types of cocoons on the basis of the norms fixed by the RMB, Chaibasa.

In Orissa, cocoon prices are fixed on the basis of silk content and are quoted per tola. For fixing price, the Apex Society has evolved a formula under which weight of 5/10/20 samples (80 cocoons each) is taken. Prices are based on labour component of production and cost of cocoons in Madhya Pradesh. In West Bengal and Maharashtra, generally the prices are fixed on the basis of grades fixed by RMB, Chaibasa. Cocoons are classified into four grades depending on the quality in Andhra Pradesh. Central Silk Board (through RMB)
fixes prices for different types of cocoons for procurement from producers or government agencies periodically (Jahagirdar, 1998).

**Indian Wild Silks Export:**

Non-mulberry silks are abundantly found in remote regions, on hill tops and in forest interiors of Myanmar, China, India, Korea and parts of equatorial Africa and South-East Asia. Although entomologists visualized five hundred types of moths spinning silk cocoons, only a few have commercial value. Tasar, Eri and Muga are the three commercially known wild silks. Wild silks which accounts for 8.23% of the total silk production is of considerable importance in the Indian context (Koshy, 1998).

The versatility of Indian wild silk is unmatching. The silk fabric produced by our traditional craftsmen is found increasingly accepted by the changing fashionable world of Europe and USA. Fashion means variety, fantasy, innovation, vitality and versatility. All these are the hallmark of Indian wild silks. The vibrant colours and wide spectrum of woven designs fascinate the fashion conscious westerners which bear testimony to the skill, artistry and aesthetic sense of our weavers. Tasar silk has greater commercial importance especially in exports and India is next only to China in Tasar silk production (Koshy, 1998).

In Maharashtra, tasar cultivation is traditionally practiced by Dhiwar communities in the districts of Bhandara, Chandrapur and Gadchiroli (Fig-2) since 200 years. The tasar development Corporation of Vidharba Limited, Nagpur, has taken keen interest in tasar sericulture. The Government of Maharashtra implemented the Inter State Tasar Project with the assistance of Swiss Development Co-operation in above district of Maharashtra. In Maharashtra, Sericulture was in hand of State Khadi & Village Industries Board, Development Corporation of Vidharba Limited, Nagpur and Directorate of Industries (Kamdi, 1998). However for giving fillip to tasar culture a separate
Directorate of Sericulture has been developed under administrative control of Textiles ministry of Govt. of Maharashtra.

a) In Maharashtra, host Plantation area under natural food plantation in forest and revenue sector is about 4000 ha.

b) The total area under economic food plantation under department 500, 400 and 200 ha in Chandrapur, Gadchiroli and Bhandara, respectively.

c) The economic plantations of *T. arjuna* raised by the forest department is 205, 313 and 263 ha in Chandrapur, Gadchiroli and Bhandara, respectively.

e) A modern cocoon market complex is established at Armori, for purchase of cocoons from the rearers and storage.

f) State Govt. developed five tiny reeling units and one median reeling unit.

**Production**

During 1997-98 the production of dfils and cocoons were recorded as 1,30,186 and 44, 89,400 respectively. Presently, more than 4000 ha of natural tasar food plantation in the state. Around 2000 skilled tasar rearers are interested in the business but, not able to take up rearing by this natural food plantation due to Forest Act. Likewise there are 781 ha food plantation, available under Social forestry scheme. About, 550 beneficiaries are getting advantage through tasar silkworm rearing in the state. In the year 2006-2007 the raw silk production in Maharashtra was 85 mts mainly from tasar (50mts) and eri 35mts, (Jadhav et al., 2007).

Considering the importance of wild sericulture in socioeconomic development of tribal population and the country, the present topic is selected and completed in Western Maharashtra (Fig-3) visualizing 24 collection spots (Fig-4) of the districts Pune (7), Satara (5), Sangli (5) and Kolhapur (7).