

ROLE OF FOREST BIODIVERSITY IN CONSERVATION OF NON-MULBERRY (VANYA) SILK IN INDIA

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ABSTRACT: The world's species diversity is described as 1.75 million out of the possible 12 to 100 million species and insect group comprises the largest diversity among all living organisms with 9.50 lakh described species. Biodiversity forms a still largely explored treasure that is severely endangered due to a huge amount of destructive human interventions. Changes in land use, habitat reduction and fragmentation, nutrient enrichment, and environmental stress, caused by human beings in the form of pollutants lead to reduced biological diversity on all levels (genes, species, and communities) and all functional roles. The Food and Agriculture Organization of the United Nations estimated that about 13 million hectares –an area roughly equivalent to the size of Greece, of the world's forests are cut down and converted to other land uses every year. The non-mulberry (vanya) silk industry is depending primarily on the productivity of forest eco-system. The vanya silkworm germplasm have several idiotypes and wild counterparts in nature. Due to their strong endemism, the metapopulation structures of these wild silkworms are highly sensitive to the present biodiversity crisis contributed by deforestation, fragmentation of forest land, environmental pollution and climate change. The North East India is considered as the hotspot of ser-biodiversity with diverse forest based food plants and sericigenous insects which play a significant role in sustainable rural livelihood and poverty alleviation in the country. Globally India is the second largest producer of silk and contributes about 15.5 % to the total world raw silk production and generates employment to 6.8 million rural people mostly women folk. The present paper deals with the present status of wild silkworm germplasm and their food plants available in North East India and maintained at Germplasm Conservation Centre, Central Muga Eri Research & Training Institute, Chenijan (Jorhat). The prospects for commercial exploitation of some perennial forest trees such Borpat, *Ailanthus grandis*, Borkesseru, *Ailanthus excelsa* and Maiphak, *Evodia (Tetradium) meliaeifolia* in eri silk sector have documented in the present study. The realistic approaches, strategies and intervention frameworks (both short term and long term) for conservation and commercial exploitation of vanya silkworm germplasm and their food plants have been discussed.

KEY WORDS: vanya silk, conservation, eri silkworm, forest, bio-resources

The present species diversity of the world is though described as 1.75 million out of the possible 12 to 100 million species (Hawksworth & Kalin-Arroyo, 1995). The insect group comprises the largest diversity among all living organisms with 9.50 lakh species out of 13.2 lakh animalia species (Fig. 1). The species richness of most groups of organisms' peaks in the tropics, with rainforests is being particularly diverse. The maximum richness of plant species is mostly found near to the equator.

Biodiversity forms a still largely explored treasure that is severely endangered due to a huge amount of destructive human actions. The current rate of species extinctions due to anthropogenic actions will result in the irreversible loss of genetic diversity, and likewise of metabolic construction plans. It can be easily

predicted that the losses for agriculture, pharmaceuticals, and many other fields of basic and applied sciences like sericulture will be severe and losses will hamper the development of future research strategies and technological innovations (Barthlott et al., 2005). Changes in land use, habitat reduction and fragmentation, nutrient enrichment, and environmental stress, caused by human beings in the form of pollutants, lead to reduced biological diversity on all levels (genes, species, and communities) and all functional roles. These accelerate the widespread extinction of bulk quantity of flora and fauna during last five centuries which are popularly known as 'the era of extinction', during which the earth has lost 200 known animal species but 400 unknown plant species each year (Koopowitz & Kaye, 1990). It is evident from reports that since 1980, the extinction rate was extraordinarily high with an annual extinction rate of 27,000 species, i.e. one species in every twenty minutes (Wilson, 1992). At this rate in 2000 AD, the number of plant species lost from the earth estimated as 40,000. The extinction of one plant species leads to extinction of several dependant animal species, which threaten the existence of human beings (Hazarika & Bhuyan, 2006). The anthropogenic actions lead to the erosion of natural forest specially the tropical forest. Till 1974, Norman Myer, a leading ecologist, estimated the loss of tropical forest ecosystem at 243200 km² per year. This might have increased manifold till date resulting in loss of habitats for many animals at the rate of 0.8 %-2 % per year (May et al., 1995), resulting in extinction of 16 million population per year or one individual in every two second (Hughes et al., 1997). The Food and Agriculture Organization of the United Nations (FAO, 2006) estimated that about 13 million hectares –an area roughly equivalent to the size of Greece- of the world's forests are cut down and converted to other land uses every year. Forest fragmentation can jeopardise the long term health and vitality of forest ecosystem. Forest fragmentation can also result in species loss as the size of a forest become too small to support a viable population of a certain plant or animal species, which is more prominent in South East Asian Countries including India (Fig. 2).

The North Eastern Region of India has got unique place in the silk map of the country producing all the four commercially exploited silk varieties namely, muga, eri tassar and mulberry silk. India is considered as hot spot of seriodiversity particularly in case of non-mulberry (vanya) silk sector and the region has emerged as its epicentre. The production and sustenance of different vanya silk varieties are directly as well as indirectly depend on forest trees, which are otherwise act as food plants for these silkworms. Hence the productivity of vanya silk depends on the health of the natural as well as artificial (cultivated) forest ecosystem. North East India including the Himalayan region is included in the 'Indo-Burma hot spot' (Myers et al., 2000), which reflects that the region is vulnerable to high rate of depletion of bio-resources. One of the important decisive factor to declare a particular region as the hotspot is the degree of threat to endemic species through habitat loss that is alarming very high in North East India (Hazarika & Bhuyan, 2006). The original extent of primary vegetation of Indo-Burma region was 2,060,000 Km², which has reduced to 100,000 km² in recent days, estimated at 4.90 % of the original vegetation (Myers et al., 2000). The data reflects that we have lost more than 95 % of our primary vegetation which includes host plants of silkworms mainly non-mulberry germplasms. It has been reported that the large scale conversion of muga food plantations (18.75 % to 32.93%) into other plantations mainly tea in three districts of Upper Assam during 2009-2012 due to environmental pollution contributed by pesticide application in tea-agro ecosystem and burning of hydrocarbons in oil fields

(Ahmed et al., 2012) causing a major threat to muga silk industry. It is needless to mention that loss of a food plant is directly related to the loss of silkworm germplasm as well. Considering the above facts, it is high time to address the conservation and commercial exploitation of non-mulberry (vanya) silk host plants and silkworm germplasm to sustainable livelihood of different stakeholders of the silk industry.

The Wild Silk Moths-An Overview

Most of the wild silkmths, under the family Saturniidae are distributed and confined with South East Asia (Peigler, 1993) and North East India is the epicentre of evolution of vanya silk moths. The food plant distribution and distinct climatic conditions of South East Asian countries impart congenial environment for occurrence and growth of the saturniid moths. Fairly good numbers of references are on record about seri-biodiversity and their potential as a source of natural silk in Indian subcontinent (Arora & Gupta 1979; Thangavelu, 1991; Nassig et al., 1996; Chinnaswamy, 2001; Thangavelu et al., 2002). Arora & Gupta (1979) estimated as many as 40 species in India alone. Jolly et al. (1975) reported about 80 species occurring in Asia and Africa to produce wild silk of economic value. Nassig et al. (1996) has mentioned that the family Saturniidae comprises of about 1200-1500 species all over the world of which the Indian subcontinent, extending from Himalayas to Sri Lanka may possess over 50 species. Out of 160 identified species of non-mulberry sericigenous insects, 100 species are found in India (Hazarika & Bhuyan, 2006). The North-Eastern Region of India makes ideal home for a number of wild sericigenous insects and is epicentre of wild silk culture including muga, *Antheraea assamensis* Helfer, eri, *Samia ricini* (Donovan) and oak tasar, *Antheraea proylei* Jolly (Peigler & Naumann 2003). About a dozen of saturniid moth species found in the Sub-Himalyan belt especially in North Eastern Region of India (Choudhury, 1981). The genus *Antheraea* is distributed within the South East Asia for its distinctive ecological requirement along with host plants in the natural forest (Hazarika & Bhuyan, 2003). Hence, the saturniid as well as *Antheraea* biodiversity exists in NE Region.

However, the diversity of wild sericigenous insects in the region is not fully explored. Given the rapid changes in land use pattern, it is pertinent to explore, characterize, conserve and document the status of these precious faunal species in the region (Ahmed & Rajan, 2011). Singh & Chakravorty (2006) enlisted 24 species of the family Saturniidae from North East India, including three species of wild silk moths namely, *Antheraea assamensis*, *Antheraea roylei* and *Attacus atlas* from Nagaland. Ahmed et al. (1996) studied detail bio-ecology of wild silk, *Cricula trifenestrata* Helfer. According to Peigler (1993) the domesticated eri silk worm, *Samia ricini* (Donovan) is not really a distinct species but a form derived from *Samia canningi* through centuries of selection for silk production which is distributed throughout the region. Kakati & Chutia (2009) recorded the presence of 14 sericigenous species belonging to 8 genera i.e. *Antheraea*, *Actias*, *Attacus*, *Archaeoattacus*, *Cricula*, *Loepa*, *Samia*, *Sonthonnaxia* and a large number of host plants. Out of the above mentioned different sericigenous saturniid silk moths, only few silk moths namely, muga, *Antheraea assamensis* Helfer, eri, *Samia ricini* (Donovan), Oak tasar, *Antheraea proylei* J. and tropical tassar, *Antheraea mylitta* D. has been commercially exploited and farmers are practising these vanya silk culture for their livelihood.

Promising unexplored wild silk moths:

It is evident from above studies that there are lots of wild silk moths available in NE Region of India but only few have been commercially exploited for economic utilization in silk sector. However, the species which require immediate attention for utilization in silk sector or any other viable sectors such food, pharmaceuticals etc. are highlighted below.

Fagara Silk (*Attacus atlas* L.): *Attacus atlas* L. (Lepidoptera: Saturniidae), a wild silk moth which is known as *fagara* silk (Jolly et al., 1979) is the world largest lepidopteran moth in terms of its wings surface area (400 cm²) (Watson & Whally, 1983) and behind only Ghost moth, *Thysania agrippin* in terms of its wingspan, which is 32 cm in case of *T. agrippin* and 25-30 cm in case of *A. atlas* (Moucha, 1966). The caterpillar of *A. atlas* is highly polyphagous and it feeds on a variety of leaves including *Muntingia calabura*, *Annona muricata*, *Cinnamomum verum*, *Nephelium lappaceum*, *Psidium guajava*, *Sandoricum indicum*, *Citrus sp*, *Cinchona officinalis*, *Cinnamomum camphora*, *Coffea arabica*, *Curcuma longa*, *Elettaria cardamomum*, *Persea americana*, *Litsea polyantha* and other trees.

The natural incidence of *A. atlas* caterpillar on *Ailanthus excelsa* was recorded at Chenijan, Jorhat with peak incidence during May-October. The caterpillars voraciously feed on the leaves and in certain cases, the trees are completely defoliated. The average larval duration recorded 23 days during May-June period. After reaching 10-11 cm in length, the caterpillar starts pupation in the plant covering with mature leaves. The brown colored cocoons are formed by spinning a silky covering (taking around 20- 24 hours) that is interwoven with desiccated leaves. The adult emerges from the pupa in the early morning hours and total pupal period was recorded 22 days. The average cocoon weight (g) was 14.11 and 10.29 for female and male, respectively. The average shell weight of single cocoon (g) recorded 2.04 and 1.84 for female and male, respectively which is five times more than shell weight of *S. ricini*. The adult longevity was 10-12 days. The females are sexually passive, only releasing pheromones to attract a male for mating. After emergence of moths, the coupling of male and female moth continued for 4-6 hours and started egg laying on the underside of leaves or the bark of the trees. Eggs are around 2.1-2.6mm in diameter and the caterpillar hatched from the eggs after 17-22 days during summer season. The Japanese designers have developed diversified products out of the *Attacus* spun yarn in recent days.

Wild eri silk moth (*Samia canningi* Hutton): *Samia canningi* is a moth of the Saturniidae family. It is found in south-eastern Asia and China. The wingspan is 100-140 mm. The larvae mainly feed on *Ailanthus altissima*, *Prunulaurocerasus*, *Ligustrum* and *Syringa* species. It has been found highly polyphagous like domesticated *S. ricini* and found feeding on Kesseru (*Heteropanax fragrans*), Borkesseru (*Ailanthus excelsa*), Borpat (*A. grandis*), payam (*Evodia flaxifolia*) and Soalu (*Litsea polyantha*) etc. Pupation takes place in a silken cocoon on the leaves of the tree in outdoor condition. Cocoons are compact and brown in colour. The average cocoon weight and shell weight is 3.46 g and 0.446 g, respectively. The shell ratio recorded is 12.86% and fecundity in indoor condition ranges from 195-265. Hence, the economic characters at par with domesticated eri silk, *S. ricini*. The natural incidence is observed throughout the year with peak incidence during May-June.

Amphutokoni Muga (*Cricula trifenestrata* Helfer): The saturniid leaf eating caterpillar, *Cricula trifenestrata* Helfer is locally known as “*Amphutokoni muga*” was considered as serious pest of som plantation as its incidence is more during commercial muga crops i.e. Kotia (September-October). The smallest wild saturniid silk also feeds mango, cashewnut, pepper, tea, litchi and ber etc. Indonesia is well known for its silk textile derived from wild silkworm cocoon of *Cricula trifenestrata*. *C. trifenestrata* is one of the world wild species of silkworms which habitats in Java island and South East Asia. *Cricula trifenestrata* produces golden silk floss which is very luxurious and amazing. Besides, spun yarn is used for production of diverse fabrics, the use of discarded sericin of *Cricula trifenestrata* cocoon extract from the water waste of silk textile industry as biomaterials will be beneficial for the local silk textile industry and also the development of natural biomaterials as bone substitute (Sunarintyas et al., 2012).

Germplasm of Eri silkworm

Eri silkworm *Samia ricini* (Donovan) under the family Saturniidae is the only domesticated, multivoltine and polyphagous silkworm among the vanya silks. Eri silkworm is the hardiest species among commercially exploited silkworms. North East India is considered as the centre of origin for eri silkworm, *Samia ricini* (Donovan). The eri culture has recent days introduced to many non-traditional states of India like Andhra Pradesh, Gujarat, Madhya Pradesh, Chhattisgarh, Tamil Nadu, Karnataka, Maharashtra, Uttaranchal, Uttar Pradesh, Jharkhand, Bihar, West Bengal, Orissa and Sikkim. Over the period of a decade annual production of Eri raw silk has significantly increased to 3105.00MT in 2011-12 from 974 MT in 1999-2000. About 1.83 lakh families with plantation area of 26000 hectares of North East India are involved in eri culture sharing about 73% of the total raw silk production in India.

Brahmaputra valley of Assam and its adjoining foot hills in the Sub-Himalayan belt is believed to be the native place of eri. The silkworm name of 'Eri' derives from the Assamese word '*Era*' which means castor the main food plant of eri silkworm. The history of silk in Brahmaputra valley can be traced back to the vedic literature (around 1600 BC). Silk from Brahmaputra valley was marketed to Mugadh, Mithila and Brahmadesh during 1340 BC. During the period of great king Bhaskar Barman of Kamrup (600-650 AD.), silk trade from Assam to North India was at peak stage. Buddhist visitor, Hieun Tsang mentioned in his writing Suvarnkusi (Sualkuchi) as an important silk producing centre. King Harsha Vardhana of Kaunuj imported silk from Assam for making his royal dresses. Later during 1492-1520 AD, the great 'Ahom' King Sarna Narayan of Sivasagar patronized silk industry of Assam.

The structure of the genitalia, wing pattern and chromosome number demonstrates that *Samia ricini* (Donovan) is derived from its wild form, *Samia canningi* (Hutton). Several eco-races like Borduar, Titabar, Khanapara, Nongpoh, Mendipathar, Dhanubhanga, Sille, Kokrajhar, Diphu, Kokrajhar, Genung etc. of eri silkworm are available in N.E. region and the germplasm conservation centre under Central Silk Board, Lahdoigarh maintains 26 numbers of ecoraces. Listing of passport data of all accessions available in the GPB is presented (Table.1). Among the presently maintained eco-races in the GPB Borduar, Genung, Diphu, Kokrajhar are showing better performance (Sarmah et al., 2012). Analysis of the growth and economic traits of cocoon of different eri silkworm races revealed that eri silkworm accession viz. SRI-001, SRI- 010 and SRI- 024 are the most promising eri silkworm races for commercial exploitation in agro climatic

condition of North eastern region of India (Sarkar, 2008). Depending upon larval colours and markings, six pure line strains were isolated from Borduar and Titabar eco races, namely, Yellow Plain (YP), Yellow Spotted (YS), Yellow Zebra (YZ), Greenish Blue Plain (GBP), Greenish Blue Spotted (GBS) and Greenish blue Zebra (GBZ).

Six pure line strains of eri silkworm had been selected and crossed following the diallel crossing technique and analyzed following Griffing's method. After combining ability studies among the six pure line strains two eri crosses viz., ES-1 (YZxGBS) and ES-2 (GBSxGBZ) have been developed (Debaraj, 2001). Field trial of two eri crosses revealed better performance in ES-1 in terms of fecundity, hatching, cocoon weight, shell weight, shell ratio, and yield (Table 2). To develop high yielding breed of eri silkworm in term of shell weight and fecundity utilizing the ecoraces like Borduar and Genung is under progress (Sinha, 2008).

Forest biodiversity and eri silkworm food plants

The total forest cover of India as per 'State of Forest Report 2003' is 678,333 km², which constitutes 20.64 % of the geographic area of the country and plays a significant role in biodiversity protection, global environment conservation, soil conservation, headwater conservation, health, recreational and cultural, material production (silk, timber, food such as mushroom etc, fertilizers, feeds, raw material for pharmaceutical and other industrial products, extracted ingredients, greening materials etc). These huge forest bio-resources may effectively be utilized for conservation and economic exploration of sericigenous insects for sustainable rural livelihood and poverty alleviation which is the major issue of developing country including India. The productivity improvement in mulberry sericulture sector is stagnant in spite of technological intervention in silkworm improvement as well as host plant management. However, growth rate of vanya silk is quite encouraging (31.16%) due to effective utilization of forest cover, improvement of rearing techniques, effective technological support in post-cocoon sectors. The North Eastern states, Jharkhand and Chattisgarh states of India are primarily dominated by tribal populations. The vanya silks are practiced mostly by these tribal and socio economically disadvantaged sections of the society.

Considering these facts, the Government of India under Forest (Conservation) Act, 1980 has issued notification in respect of vanya silk cultivation. Under this Act, the State/UT Forest Department should encourage silk cultivation in forests areas by tribals and non-tribals who live in and around the forests and are dependent on such forests for their livelihood. However, priority should be given to the tribals and to those enjoy traditional rights on such forests. The State/UT Forests Departments should permit such activities in already identified naturally grown forest areas for silk cultivation and the plantation raised for the purpose thereof in coordination with the State/UT Sericulture Department and Central Silk Board. Cultivation of trees on which vanya Silks or silk worms of Tasar, Oak Tasar, Muga, Eri and Frithi could be reared by tribals and non-tribals living in and around the forest areas for their livelihood without undertaking monoculture plantations should be traded as forestry activity. Therefore, no prior permission of the Central Government under Forests (Conservation) Act, 1980 is required.

Eri-silkworm *Samia ricini* (Donovan) is highly polyphagous in nature feeding on a number of host plants viz., Castor, *Ricinus communis* Linn; Kesseru, *Heteropanax fragrans* (Roxb.) Seem; Tapioca/Cassava, *Manihot esculanta* Crantz; Korha, *Sapium eugenifolium* Buch-Ham; Payam, *Evodia flaxinifolia* Hook; Borpat, *Ailanthus grandis* Prain; Borkesseru, *Ailanthus excelsa* Roxb;

Gulancha, *Plumeria acutifolia* (Poir); Papaya, *Carica papaya*; Bangali era, *Jetropa curacus* Linn and several others. Further, one forest tree popularly known as 'Maiphak', *Evodia (Tetradium) meliaefolia* Benth under the family Rutaceae has been recorded as an alternative food plant of eri silkworm (Fig. 7).

Most of these plants are grown in natural forest in N.E. Region of India as well as in other parts of the country. The CMER&TI, Lahdoigarh has initiated the projects on collection, conservation and evaluation of different perennial food plants so that forest biodiversity may be utilized in eri silk industry. Some of the perennial food plants covered under the projects is highlighted below.

Tree of Heaven (*Ailanthus* species): *Ailanthus* (derived from *ailanto*, an *Ambonese* word probably meaning "tree of the gods" or "tree of heaven") is a genus of trees belonging to the family Simaroubaceae. The genus is native from East Asia south to northern Australasia. They are fast-growing deciduous trees growing to 25-45 m tall, with spreading branches and large (40-100 cm) pinnate leaves with 15-41 long pointed leaflets, the terminal leaflet normally present, and the basal pairs of leaflets often lobed at their bases. The number of species is disputed, with some authorities accepting up to ten species, while others accept six or fewer. There are four to five species are available in India, which is distributed though out the country. A silk spinning moth, the *Ailanthus* moth, *Samia cynthia* feeds on *Ailanthus* leaves, and yields a silk more durable and cheaper than mulberry silk, but inferior to it in fineness and gloss. This type of silk is known under various names: "pongee", "eri silk" and "Shantung silk", the last name being derived from Shandong Province in China where this silk is often produced. Its production is particularly well known in the Yantai region of that province. The moth was also introduced in the United States (Li, 1993). Other Lepidoptera whose larvae feed on *Ailanthus* include *Endoclyta malabaricus*. Several species of Lepidoptera utilize the leaves of *ailanthus* as food, including the Indian moon moth (*Actias selene*) and the common grass yellow (*Eurema hecabe*). In North America the tree is the host plant for the *ailanthus* webworm (*Atteva aurea*). In its native range *A. altissima* is associated with at least 32 species of arthropods and 13 species of fungi (Zheng et al., 2004).

The number of species of *Ailanthus* is disputed, with some authorities accepting up to ten species, while others accept six or fewer. The different *Ailanthus* species and their distribution are presented in the Table 2.

Chowdhury (2006) reported that four species exist in India, such as; *A. excelsa* (Borkesseru), *A. grandis* (Barpat), *A. altissima*, and *A. malabarica*. The first one is found in northern India, the second in Arunachal Pradesh, the third in Kashmir and the last one in Malabar Coast. *A. excelsa* is indigenous to India and more common in Bihar; Gujarat, Madhya Pradesh, Orissa and South India. In addition to its use as an ornamental plant, the tree of heaven is also used for its wood, medicinal properties and weed management. There are different genotypes of *Ailanthus* found in nature.

The present study on distribution of *Ailanthus* germplasm indicates that *A. excelsa* is available throughout N.E. Region i.e. Arunachal Pradesh (Papumpare district), Foothills of Nagaland, Bodo Territorial Council, Karbi Anglong and Manas reserve forest areas of Assam, Meghalaya. Further, *Ailanthus excelsa* and *A. trypsia* (syn. *malabarica*) is available in U.P., Rajasthan, Pune, Odisha, North Karnataka, Tamil Nadu, Kerala and Andhra Pradesh etc. The tree is indigenous to Southern and Central India and distributed in Western Peninsula, Rajasthan, Bihar, Orissa, Bundelkhand, throughout Madhya Pradesh, Broach and Panchamal district of Gujarat, in dry deciduous forests of Maharastra, scrace in

Deccan and Karnataka, N. Circars, forest of Tamilnadu. It is often planted along the roads (Kumar *et. al.*, 2010). The present study also reflects that the distribution of *A. grandis* is restricted to N.E. Region only such as Kimin forest areas, Chessa forest and adjoining foothills and West Siang district, Tinsukia district, Manas forest area and Nambor reserve forest.

The phyto-chemical studies on *A. excelsa* demonstrated the presence of quassinoids, flavonoids, alkaloid, terpenoids, and proteins (Ogura *et al.*, 1977; Sherman *et al.*, 1980; Nag & Matai, 1994; Loizzo *et al.*, 2007). *A. excelsa* extracts and some isolated compounds have demonstrated medicinal properties such as significant antileukemic, antibacterial, antifungal and antifertility activities (Ogura *et al.*, 1977; Dhanasekaran *et al.*, 1993; Shrimali *et al.*, 2001; Joshi *et al.*, 2003). Phukan *et al.* (2006) reported that *Ailanthus grandis* Prain (Simaroubaceae-Quassia family) as an alternate food plant of eri silkworm.

Use of *A. excelsa* leaf at the last two stages save eri leaf requirement as the worm is a glutton (Chowdhury, 2006). Narayanswamy *et al.* (2006) studied the activity of amylase in digestive juice and hemolymph in eri silkworm and reported that the relationship was stronger for both castor and borkesseru than cassava. Hence, borkesseru could be exploited as suitable substitute for castor to rear eri silkworm. Saritha *et al.* (2009) also reported that the amylase activity of eri silkworm fed on Borkesseru (*Ailanthus excelsa*) was at par with those fed on castor. The present preliminary studies on evaluation of perennial food plants indicate that rearing performances (ERR, cocoon weight, shell weight and fecundity) of eri silkworm feeding on *Ailanthus grandis* (Borpat) and *Ailanthus excelsa* (Borkesseru) is better than *Heteropanax fragrans* (Kesseru) (Table 3). Further, Borpat and Borkesseru can be utilized throughout the year unlike Kesseru which shows comparative poor performance during summer crop (June-July). As castor leaf is not available throughout the year in farmer's field, the Borpat and Borkesseru are the best alternatives for sustainable eri silkworm rearing.

The data reflects that the biomass production in *Ailanthus* species is much higher than other perennial food plants and castor. Hence, utilization of *Ailanthus* plant in the eri silkworm may improve the rearing capacity of eri silkworm rearers by 2-3 times which is required for commercialization of the ericulture (Table 4). Further, *Ailanthus* species are forest based trees, so it may explored for livelihood security to the forest dwellers that are otherwise depend on tree felling causing large scale deforestation.

Strategies of conservation of sericigenous biodiversity

- ✓ Collection and maintenance of data bank on taxonomy, phenology, habitat preference, breeding system, and minimum population size of the sericigenous wild germplasm along with mapping of population, information on density within the site and interaction of species with the surrounding environments.
- ✓ Besides exploration of improved breed out of the existing eco-races of eri silkworm, it is also important of other concept of aiming at collection and maintenance of new species of eri silk moths from the field, if any, may be important from the standpoint of new concept for the future. It is well known that improvement of production and productivity of eri silk moths using existing stock in the laboratory is surely important, but

finding eri silk moths with extreme characteristics, such as having very fine filament of cocoons or having very thick filament of cocoons are also important. Because they are useful for development of new textiles with characteristic properties we cannot find elsewhere but in India or finding eri silk moths with extremely short life cycle, if any, is a source for future development.

- ✓ The genetic resources are renewable in nature or in similar *ex-situ* conservation with their proper management can fulfill human needs in larger extent.
- ✓ Proper inventorization of seri-biodiversity is need of the hour to productivity enhancement.
- ✓ Development and strengthening of *in situ* mechanism for seri-biodiversity conservation in forest and outside the protected areas.
- ✓ Collaboration among different stakeholders in national as well as regional level in the areas of policy, planning and R&D.
- ✓ Involvement of local communities, general public and scientific professionals for protection of the reserve. Further, strengthening of social capital of primary stakeholders should be emphasized for protection of seri-diversity as well as its sustainable utilization.
- ✓ Utilization of eri pupae in health and food industry is another promising filed for exploitation. Prof. Sumida had been supporting making medicinal mushrooms on Bombyx pupae to make so called 'winter insect summer grass' in a company in Japan. The company now sells the products as health foods. We believe some efforts will be needed to culture the medicinal mushrooms on eri pupae.

CONCLUSION

The concept of biodiversity conservation and gene bank maintenance have gained greater momentum in the recent times and the biodiversity wealth are considered as common heritage of mankind and sovereign rights of the nations. Seri-biodiversity refers to the variability in sericigenous insects and their host plants, which are economically and ecologically important biodiversity and by and large, forest based. There are several wild sericigenous insects and their host plants, which are abundant in the North Eastern and sub-Himalayan regions and other parts of the country. However, only five types of sericigenous insects are commercially exploited in India and there remains a great scope for producing novel silk from *Cricula trifenestrata* and *Attacus atlas* etc. The importance of these lesser known silk producing insects and their host plants should be studies and explored for betterment of mankind .In the recent times, Japan, China, Thailand and Korea have embarked on production of various other products from silkworm and their host plants, which makes sericulture more profitable

and highly sustainable. It is now essential for India to develop allied industries related to sericulture and make total use of the food plants and silkworm for different products, particularly pharmaceutical products. Being forest based, the wild silkworms contribute to the development of sustainable natural environment, which is very much required these days, since ozone layer is very much in threat due to rapid industrialization and other man made hazards.

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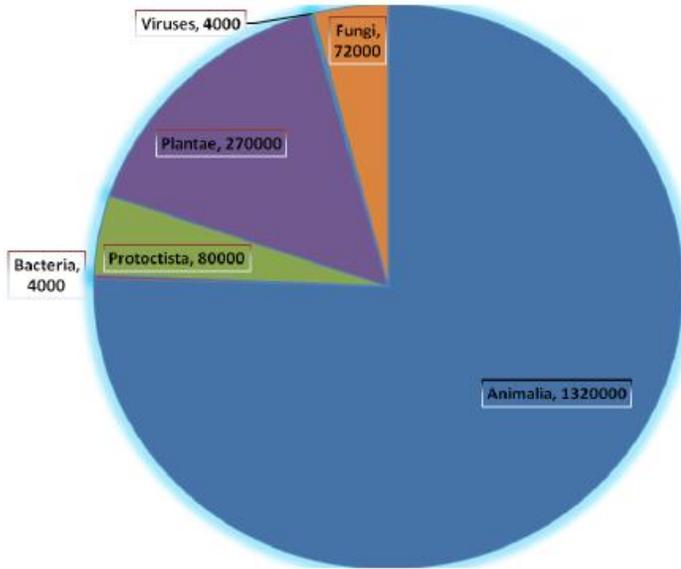


Figure 1. Number of organisms currently described (Hawksworth & Kalin-Arroyo, 1995).

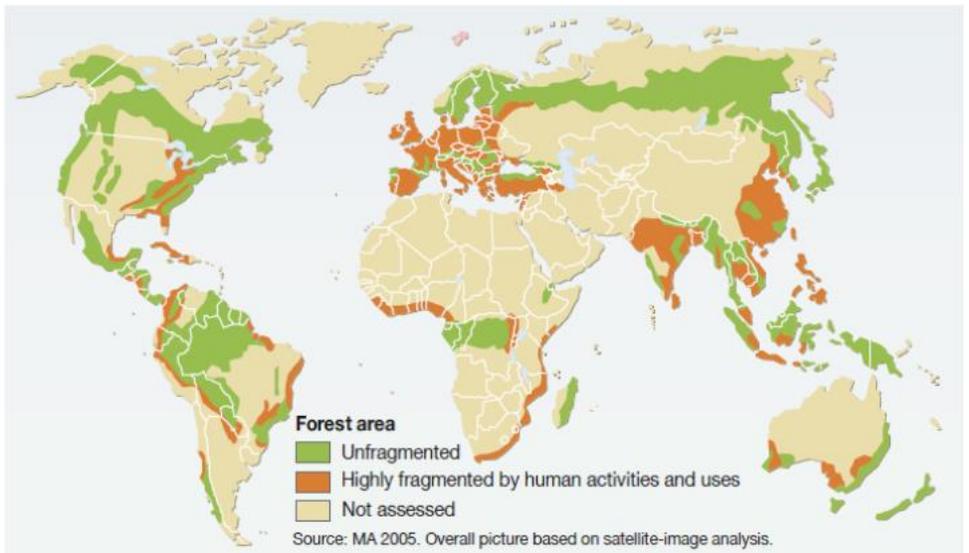


Figure 2. Global Forest Fragmentation.

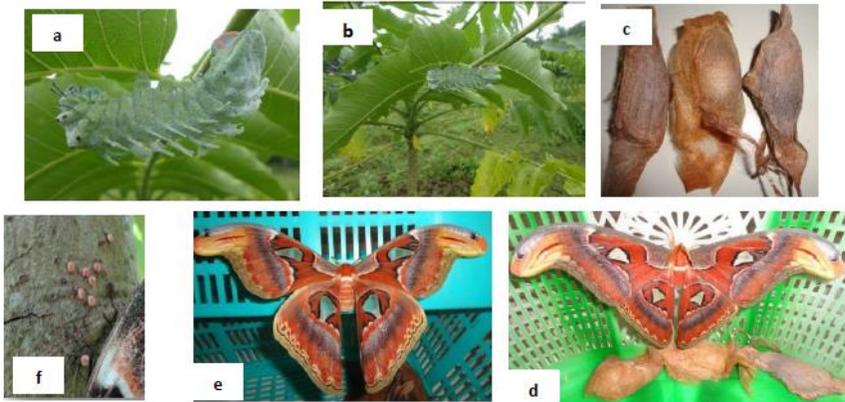


Figure 3. (a-b) *Attacus atlas* caterpillar feeding on *Ailanthus excelsa* plant (c) Cocoon of *A. atlas* (d) Male moth of *A. atlas* (e) Female moth of *A. atlas* (f) Eggs laid on bark of tree.

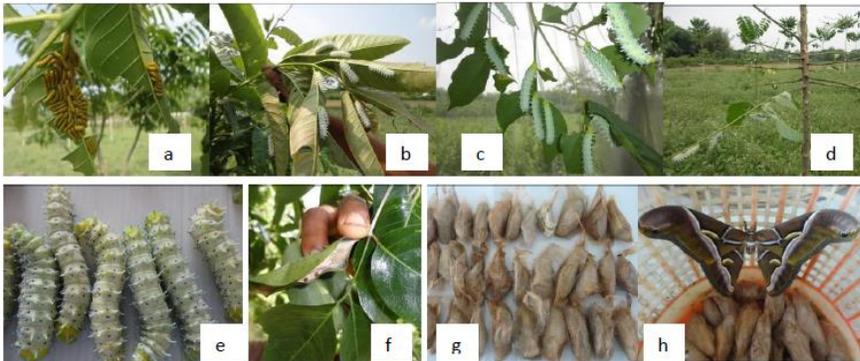


Figure 4. (a-b) *S. canningi* feeding on payam. (c) feeding on kesseru (d) feeding *A. grandis*, (e) mature larva (f) cocoon formation on leaf (g) cocoons & (h) emergence of moth.

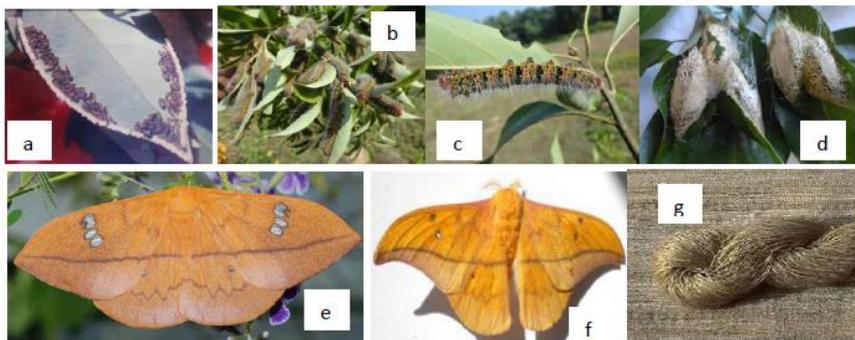


Figure 5. *Cricula trifenestrata* (a) eggs with newly hatched caterpillars (b&c) mature caterpillars (d) cocoons (e) female moth (f) male moth and (g) spun yarn.



Figure 6. Different strains of eri silkworms maintained at GCC, Central Silk Board, Chenijan.



Figure 7. (a) Maiphak plant (b) Eri silkworm feeding on Maiphak.



Figure 8. *Ailanthus grandis* germplasm at GCC, CMER&TI, Chenijan.



Figure 9. *Ailanthus excelsa* germplasm in different parts of India [(a) CMER&TI, Jorhat (b) Delhi (c) Diphu, Assam (d) St. Mount park, Chennai (e) Adabari, Kokrajhar (f) Dimapur, Nagaland (g) Khurda, Odisha and (h) Chessa forest, Arunachal.



Figure 10. (a) Rearing of Eri silkworm feeding on *Ailanthus grandis*, (b) Rearing of eri silkworm feeding on *Ailanthus excelsa*.

Table 1. Listing of Passport data of eri silkworm accessions.

Sl. No.	Accession No.	Race name	Donor	Origin	Class	Parentage
1	SRI-001	Borduar	RERS, MEG	ASM	O(RCU)	OR
2	SRI-002	Titabar	RERS, MEG	ASM	O(RCU)	OR
3	SRI-003	Khanapara	RERS, MEG	ASM	O(RCU)	OR
4	SRI-004	Nongpoh	RERS, MEG	MEG	O(RCU)	OR
5	SRI-005	Mendipathar	RERS, MEG	MEG	O(RCU)	OR
6	SRI-006	Dhanubhanga	RERS, MEG	ASM	O(RCU)	OR
7	SRI-007	Chuchuyimlang	CMERTI, ASM	NAL	N	OR
8	SRI-008	Lahing	CMERTI, ASM	ASM	N	OR
9	SRI-009	Barpathar	CMERTI, ASM	ASM	N	OR
10	SRI-010	Diphu	CMERTI, ASM	ASM	N	OR
11	SRI-011	Adokgri	CMERTI, ASM	MEG	N	OR
12	SRI-012	Lakhimpur	CMERTI, ASM	ASM	N	OR
13	SRI-013	Dhemaji	CMERTI, ASM	ASM	N	OR
14	SRI-014	Kokrajhar	CMERTI, ASM	ASM	N	OR
15	SRI-015	Imphal	CMERTI, ASM	MAN	N	OR
16	SRI-016	Cachar	CMERTI, ASM	ASM	N	OR
17	SRI-017	Dhakuakhana	CMERTI, ASM	ASM	N	OR
18	SRI-018	Genung	RERS, MEG	MEG	N	OR
19	SRI-019	Jonai	CMERTI, ASM	ASM	N	OR
20	SRI-020	Dhansiripar	CMERTI, ASM	NAL	N	OR
21	SRI-021	Sadiya	CMERTI, ASM	ASM	N	OR
22	SRI-022	Tura	CMERTI, ASM	MEG	N	OR
23	SRI-023	Jona Kachari	CMERTI, ASM	ARP	N	OR
24	SRI-024	Barpeta	CMERTI, ASM	ASM	N	OR
25	SRI-025	Ambagaon	CMERTI, ASM	ASM	N	OR
26	SRI-026	Rongpipi	CMERTI, ASM	ASM	N	OR

SRI – *Samia ricini*, RERS – Regional Eri Research Station, CMERTI – Central Muga Eri Research & Training Institute, MEG – Meghalaya, ASM – Assam, NAL – Nagaland, MAN – Manipur, ARP – Arunachal Pradesh, O – Old, RCU – Race in current use, N – New, OR – Original Race.

Table 2. Distribution of different *Ailanthus* species.

Ailanthus species	Distribution
<i>Ailanthus altissima</i>	Northern and central mainland China, Taiwan, arguably the best known species
<i>Ailanthus excelsa</i>	India and Sri Lanka
<i>Ailanthus grandis</i>	India
<i>Ailanthus integrifolia</i>	New Guinea and Queensland, Australia
<i>Ailanthus malabarica</i>	Southeast Asia
<i>Ailanthus triphyssa</i>	Northern and eastern Australia
<i>Ailanthus vilmoriniana</i>	Southwest China