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Unlocking silk production in north India: Diversification and production technologies for vanya silk

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Abstract
Sericulture is a crucial industry in India, providing sustainable livelihoods to rural and tribal communities while playing a vital role in the country's textile economy. In northern India, the states such as Punjab, Haryana, Himachal Pradesh, Uttar Pradesh Uttarakhand, and union territory Jammu and Kashmir the industry primarily focuses on bivoltine mulberry silk, leveraging the region's suitable agroclimatic conditions. Despite its potential, silk production in the region remains underdeveloped due to one or two crop yields, limited infrastructure, lack of awareness, and inadequate market access. To address these challenges and unlock the region's sericulture potential, diversification into Vanya silks like muga, eri, and tasar silk is essential. Diversification not only broadens the production base but also integrates sericulture into enhancing biodiversity, farmer incomes, and sustainability. Additionally, presence of non-mulberry host plant has been reported in the northern parts of India. The importance of adopting innovative technologies, government support programs, and collaborative efforts to revitalize sericulture in northern India. Mechanized reeling and weaving technologies combined with region-specific sericulture techniques can increase production of silk and decrease labour intensity. By embracing diversification, the region can contribute significantly to the national silk economy while promoting rural development and ecological balance.

Keywords: North India, vanya silks, agroforestry, diversification, innovations.

Introduction
Silk is the epitome of luxury; no other fabric can match its shine and elegance. Its touch evokes a complex historical tapestry, embodying unparalleled majesty. Silk has been the queen of textiles for millennia, and people have loved it throughout history. The modest caterpillar produces it in a continuous strand that stretches almost a thousand kilometres, and it is the essence of life. Sericulture has shown itself to be a successful strategy for supporting inclusive development in rural communities, especially for underprivileged populations and for ensuring fair distribution from wealthy metropolitan areas to impoverished rural areas in India. It is an effective instrument for empowering women and tribal communities because of its environmentally friendly production technique. Millions of people have access to sericulture because of its lucrative output and strong job possibilities. Silk is an integral part of Indian customs and culture, and it is used in many ceremonies and rituals. India has a long and complex history of producing and trading silk that began in the fifteenth century. Approximately 9.5 million individuals in rural and semi-urban areas are employed in the sericulture sector at the moment, and a sizable percentage of these workers are women and come from economically disadvantaged homes (Annual report CSB, 2023) [5]. India has become a global leader in the silk industry thanks to its traditional and culturally rich domestic market and its incredible variety of silk clothing that reflects regional uniqueness.

India is united in its cultural variety. Likewise, sericulture customs vary per state and are distinctive and historic. India produces different natural silks which are divided into two categories: mulberry and wild or non-mulberry. The general term for non-mulberry sericulture is "forest" or "wild." The primary non-mulberry silks are tasar, eri, and muga, which are subject to tropical and temperature changes. Other types, such as fagara, coan, mussel, and spider silks, are of little interest. Tasar silks account for over 95% of the world's non-mulberry silk production (Bukhari *et al.*, 2019) [2]. Twenty-eight states in the nation

possess inherent strength, with 25 of them and Jammu & Kashmir (Union Territory) being significant in sericulture, either for mulberry, eri, muga, and tasar, or a mix of these industries. Non-mulberry sericulture is a long-standing activity mostly among tribal communities. Their revenues from non-mulberry sericulture are moderate. For a long time, wild sericulture was considered an exclusive craft of tribal and hill people who lived in the forests of central India, the Sub-Himalayan region, and northeastern India. The northern states of India such as Punjab, Haryana, Uttarakhand, Himachal Pradesh and union territory Jammu and Kashmir are mainly involved in the mulberry sector than the non-mulberry (Seri-statistics, CSB, 2024). However, recent experiments in some northern Indian regions have promoted Vanya silkworm rearing and silk manufacturing. This would not only assist produce more silk but also diversify the sericulture sector in the northern region. Non-mulberry or wild silk, which has gained popularity among users (Verma, 2005) [28], should be prioritized for increased production. Wild silk accounts for only 1% of global silk production, but its scarcity and naturalness make it highly coveted in a niche market, resulting in higher prices for fabrics created from it (Veldtman*et al.*, 2004, Bukhari *et al.*, 2019) [2, 27].

India is unique in that it produces all five of the commercially available silks: muga, eri, oak tasar, tropical tasar, and mulberry. Of them, only India produces muga silk, which is distinguished by its unique golden yellow shine. After China, India is currently the world's second-largest producer of silk. In addition, it is the world's biggest consumer of silk. A notable increase in silk output has been observed in recent years. India produced 38,913 MT of silk in 2023-2024, up from 26,480 MT in 2013-14, at a compound annual growth rate (CAGR) of 3.6%. Approximately 77% of the nation's silk production in 2023-2024 came from mulberry silk, with eri silk making up the remaining 18%. The proportions of muga and tasar silks were 1% and 4%, respectively.

Current State of Silk Production in North India

The states in northern India that produce silk include Haryana, Punjab, Himachal Pradesh, Uttarakhand, Uttar Pradesh, Rajasthan and the Union territory of Jammu and Kashmir (CSB, 2024) [5]. These states being a traditional cultivator of bivoltine silk of international standard but unfortunately the multi-fold potential of the region is characterized with insignificant cocoon production that cannot sustain the international market. The primary limitations faced by silkworm rearers are insufficient mulberry trees (69.78%), a lack of season hybrids (58.67%), variations in cocoon rates (46.67%), competition from other crops (44.0%), and inadequate training programs (25.33%). These factors are major contributors to the expected and obtained yield gap (Sharma *et al.*, 2022) [24]. Table 1. And fig.1 Depicts the state wise silk production in the northern india (CSB, 2023) and fig.2 depicting the all the commercial silk production in the northern India

Table 1: Northern India State-wise Mulberry Silk Production (2023-24)

State/UT	Mulberry Area (ha)	Reeling Cocoons (MT)			Raw Silk (MT)		
		BV	CB	Total	BV	CB	Total
Uttar Pradesh	3856	1578	1230	2809	197	118	315
Jammu & Kashmir	6853	821		821	117		117
Himachal Pradesh	3463	233		233	25		25
Uttarakhand	3918	312		312	42		42
Haryana	340	6		6	0.9		0.9
Punjab	1249	28		28	4		4

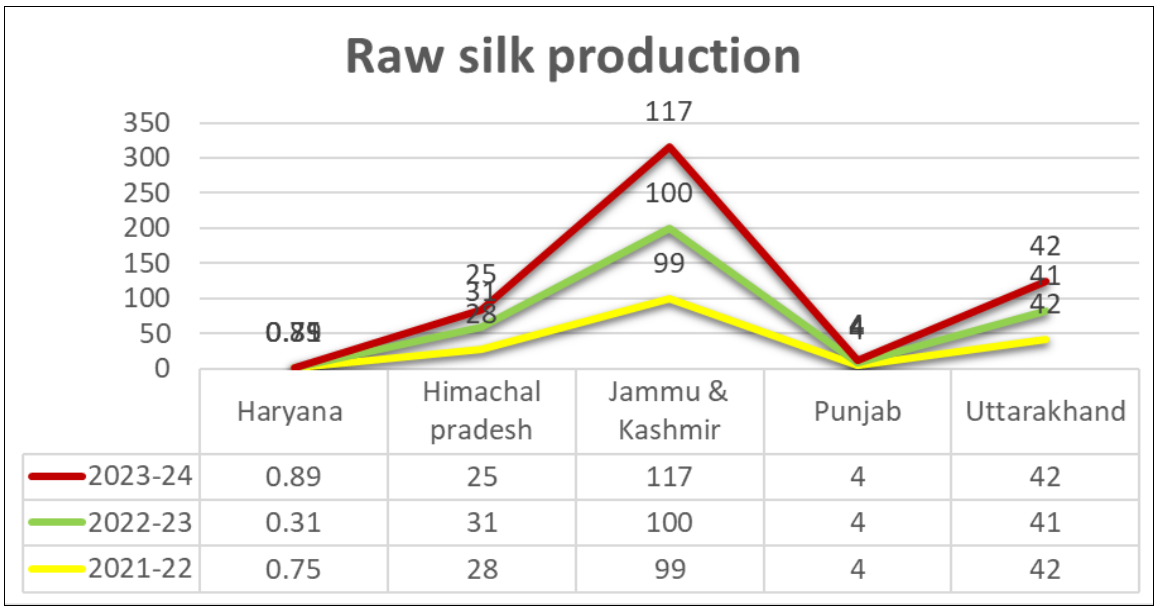

Fig 1: Mulberry Raw silk production in northern india (2022-24)

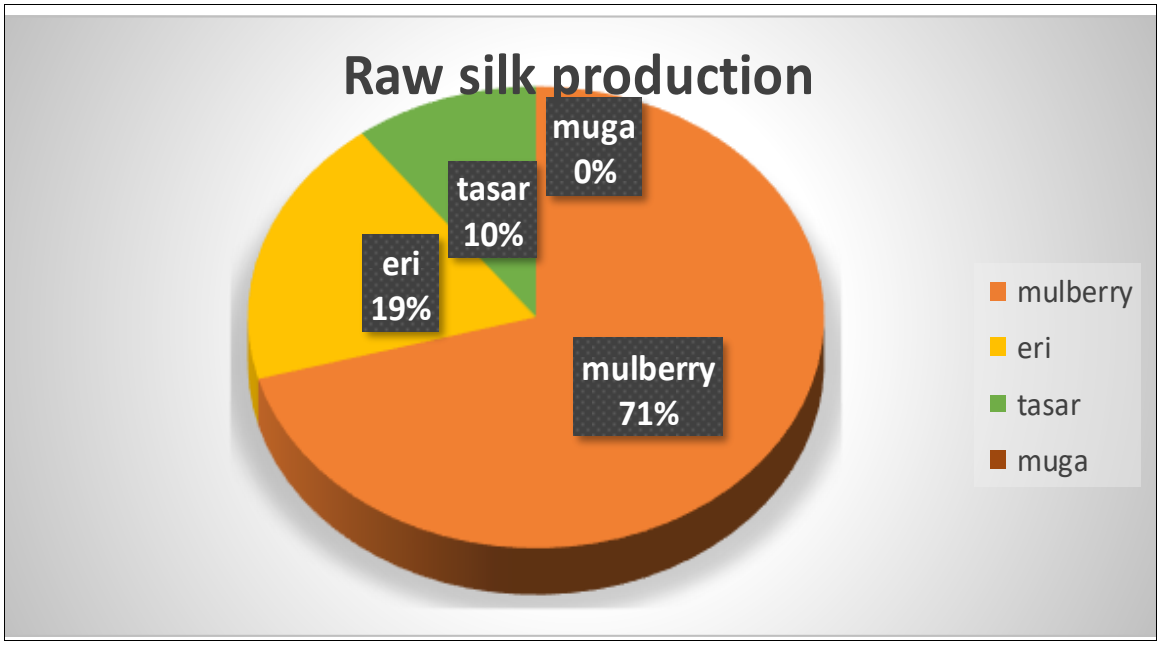

Fig 2: Raw silk Production in northern India (%)

Compared to mulberry silk production in these states, vanya silk output is subpar. Punjab and Uttarakhand with 0.3 and 0.33 spun silk production in the year 2023-24 (CSB, 2023).
Mulberry sericulture is a commercial endeavour, whereas non-mulberry sericulture, also known as wild or vanya sericulture, is a livelihood choice for tribals and other underprivileged populations. Non-mulberry sericulture includes rearing of muga, eri and tasar. Table 2. is a overview of Vanya silkworms that is exploited commercially in India (Shetty *et al.*, 2007) [25].

Table 2: Vanya silkworm exploited commercially in India

Silkworm Variety	Scientific name	Primary Food Plants		Distribution
		Local	Scientific name	
Eri	*Samia ricini*	Kesseru, Castor	*Heteropanax fragrans, Ricinus communis*	North Eastern Region, Bihar, Andhra Pradesh, Orissa, Madhya Pradesh
Muga	*Antheraea assamensis*	Som, Sualo	*Persea bombycina, Litsea polyantha*	North- eastern region
Tropical tasar	*Antheraea mylitta*	Arjun, Asan and Sal	*Terminalia arjuna, Terminalia tomentosa Shorea robusta*	Central India and Southern Plateau Region
Temperate Tasar	*Antheraea proylei*	Uyung	*Quercus serrata Q.incana Q.semicarpifolia*	Sub Himalayan region and North Eastern India

For a long time, vanya sericulture was thought to be just for tribal and hill people in Central and North Eastern India. This indigenous tradition has recently gained national attention (Roychoudhury, 2006) [23]. The country's rich production potential, steady demand for vanya silk products, eco-friendly production and processing activities, and women's participation have led to commercial exploitation of this age-old craft, transforming it into a promising industry.

Challenges in Silk Production

Although sericulture is a subsidiary industry of agriculture and is therefore well suited to boosting the nation's rural economy, it is hampered by a number of factors, including the importation of low-cost alternative textiles from other Asian neighbours, the use of antiquated manufacturing technology, antiquated and unscientific "reeling" and "weaving" techniques, the use of low-quality seeds, low production of bivoltine seeds, the use of non-graded and diseased seeds, farmers' lack of awareness of farm disease, inadequate supply chain management, massive unorganized. The disorganized sector, high production costs, periodic droughts, and rising imports of silk from China have led to challenges such as (Bukhari and Kour, 2019) [2]:

1. Prices fluctuate.
2. Lack of sufficient market
3. Long distance to market.
4. Lack of transportation facilities
5. Lack of storage facilities.
6. Inadequate information about market trends.
7. Lack of finances

Climate change is a major concern to sericulture, as changes in temperature, humidity, and rainfall can negatively impact mulberry farming and silkworm rearing.
Extreme weather occurrences, such floods and droughts, compound existing issues. Developing climate-resilient mulberry cultivars and implementing microclimate management techniques are key to ensuring the industry's viability (Lee and Kim, 2018) [17].
Silkworm disease outbreaks, volatile cocoon pricing, limited access to contemporary infrastructure and technology, and competition from synthetic textiles are some of the difficulties that sericulture producers may encounter.

Integration with Weavers: Sericulture producers and handloom weavers may have tight ties in some situations. Sericulture farmers' silk is frequently utilized by weavers to make a variety of silk goods and textiles.
Sericulture is labour-intensive and requires specialized workers for operations including mulberry farming, silkworm breeding, and silk reeling. Traditional sericulture locations have manpower shortages due to urbanization and movement of younger generations to cities (Lin and Li, 2019 and Thrilekha*et al.*, 2024) [18, 26].

Government Initiatives
The Government of India created the Central Silk Board (CSB) after realizing the enormous employability potential that was emerging throughout the silk industry's value chain. The silk industry employs 9.4 million people in rural and semi-urban areas because to its minimal capital requirements and profitable nature of production from rural on-farm and off-farm operations.
The government has put in place a number of plans and initiatives to help farmers engaged in sericulture. India's government has put in place a number of IT initiatives, training, technology transfer, and research and development programs to help the country's silk sector flourish. Creating innovative technologies, increasing workforce training, educating people, and improving communication between developers, specialists, and scientists are the main goals. The industry is being developed through a number of programs, including the Scheduled Caste Sub-Plan (SCSP), Silk Samagra, Tribal Sub-Plan (TSP), and Sericulture Development in North-Eastern States (NERTPS).
Through the Central Sector Scheme, "Silk Samagra-2," an umbrella program for the all-encompassing growth of the silk industry, the 159 CSB units spread across various States are carrying out the organization's statutory activities. With a total budget of Rs. 4679.86 crore, the Union Cabinet has approved the "Silk Samagra-2" project, which would be implemented between 2021-2022 and 2025-2026.The Scheme consists of 4 major components *viz*., 1) Research & Development, Training, Transfer of Technology and IT Initiatives, 2) Seed Organization, 3) Coordination and Market Development, and 4) Quality Certification Systems & Brand Promotion & Technology Up-gradation.
The sericulture development scheme was introduced by the Indian government as part of the "North-East Region Textile Promotion scheme." The goal of this plan is to revitalize, grow, and diversify the state's sericulture industry, with an emphasis on Eri and Muga silks.

Diversification of Sericulture
Commercial exploitation of Vanya silks dates back to the 17th century. When the European sericulture industry was wrecked by a widespread silkworm sickness in the middle of 1800, the Western world developed a taste for these foreign shaded silks. Because Asia was unable to meet the demands of Europe and North America with its mulberry silk supply, a market for Vanya silks was created.

History of Vanya silkworm
Muga: Jean Joseph Tavenier, a well-known European traveller, introduced the world to Assamese (Muga) silk in 1662. Since the Assamese kings supported the growth of sericulture, it was free from paying land revenue. The development of the muga business was hindered by the massive earthquake that struck Upper Assam in 1950, which destroyed many muga plants.

Eri
The Sanskrit word "eranda" is the root of the term "eri," which signifies castor plant. Although the origins of ericulture are lost to antiquity, it is nevertheless true that Assam was the first place where eri silk was produced, with the first recorded mention dating back to 1779. It was dubbed "Palma Christi" silk by the British. The hefty garments known as "Bar Kapoor" were fashioned from eri silk. According to Captain Jenkins (1771), eri silk had extraordinary durability.

Tasar
The ancient epic Ramayana mentions tasar silk in "Rama's nuptial gift to Sita includes tasar silk," despite the fact that there is no documented trace of the origin of tasar in India. The temperate tasar was first introduced in the middle of the 1960s and is a relatively new species.

Fagara
It is a non-commercial silkworm, which is being exploredin order to replace traditional silks with "fagara silk." Because of the silk's superior fiber properties, less taxing rearing circumstances, and thicker cocoons, it has been demonstrated that it could eventually replace regular silk (Ravi and Kumar, 2022).
Compared to other agro-enterprises, sericulture yields the largest income for farmers, which is distributed eight to ten times a year, in contrast to other crops that yield one or two times a year. Silkworm rearing should be made more common in state landless labour areas and forest-rich areas, particularly for Vanya silks, which are raised on forest plants other than mulberries. India only contributes 14.1% of the world's raw silk production, despite having a large labour force.
Therefore, by incorporating sericulture into different farming systems, this is a sector that has the potential to boost farmers' revenue (Kumar, 2018) [15]. In contrast to Mulberry and Eri silkworm rearing, Tasar and Muga are raised outdoors in natural conditions (tree-based rearings without any controlled conditions), and they are susceptible to crop losses due to unforeseen weather events and pest outbreaks (Gadad*et al.*, 2022) [7]. Nevertheless, enterprise investment is consistently low. The northern states of India mainly indulged in the bivoltine silk production has shifted the heart of the farmers towards other agriculture subsidiary due to which its decline has been seen in the recent times. Therefore, diversifying of sericulture or introducing of non-mulberry silkworm is much needed in such sericulture states for both income and employment generation. Some experimental rearing of muga silkworm in non-traditional areas since the northeast's unfavourable climate makes it difficult to raise muga silkworms, especially the seed crops, there is ample room to expand muga culture in the Dehradun hills. The situation during the seed and pre-seed crops in recently discovered areas is not as dire as it is in Assam. West Bengal, namely the Cooch Behar district, is another area that can be investigated because of the successful Muga culture there due to the climate's proximity to Assam (Arunkumar *et al.*, 2022) [1]. And introducing of eri silkworm rearing to different parts of country. Eri silk is considered to be the most renowned vanya silk in India, and

its natural home is thought to have been the Brahmaputra valley in Assam and the surrounding foothills, also they have been cultured in the other states like Tamil nadu, Andhra Pradesh, Orissa, Uttar Pradesh and West Bengal (Harishkumar and Thirupathaiah, 2023; Jena *et al.* 2024) [11, 12]. Eri silk has remarkable textile qualities and is distinct in a number of ways, such as its surface characteristics, fineness, density, cross-sectional shape, intake temperature, and insulation capabilities. Tasar silk being the 95% constituent of vanya silk which is native to central states of India such as Jharkhand, Chhattisgarh, Madhya Pradesh and other states like Orissa, West Bengal, Uttar Pradesh, Maharashtra, Bihar and Andhra Pradesh (Reddy *et al.*, 2010; Gedam *et al.*, 2023) [8, 22].

The table

Table 3: Sector-wisesericulture outline in India (Manjunatha *et al.*, 2023) [19]

Particulars	Mulberry	Eri	Muga	Tasar
Raw silk production	74.03%	21.07%	0.73%	4.17%
Major location	Southern, N&NW India	North-East India	North -East India	Central & East India
Avg. Plantation Area (Acre)	1.7	0.8	1.2	5.16
Plantation Type	Bush and tree	Road side, systemetic and forest	Block and forest	Forest followed by block plantation
Avg. Cocoon Yield	70 kg/100dfls	8.92 kg cocoons/100dfls	47 cocoons/dfls	39 cocoons/dfls
Cocoon Price Range	350-800/kg	600-1200/kg (300-400/kg Pupa)	3-4/Cocoon	4-5/Cocoon
Silk Yarn Price (Rs)	4000-5000/kg	2500-3500/kg	25000-32000/kg	4000-5000/kg

Table 4: Cost & returns of Mulberry, Muga, Eri and Tasar silkworm cocoon production per ha per year (Manjunatha *et al.*, 2023) [19]

Crop	Total Cost (Rs)	Gross return (Rs)	Yield ('00 Kg)	Net return (Rs)	Production Cost (Rs/Unit)	B:C
Mulberry	311930	516750	13	204820	235.42/kg	1.66:1
Muga	115930	240000	960**	124070	1.20/Cocoon	2.07:1
Eri	190745	344000	0.8 (2.4*)	153255	867.02/kg	1.88:1
Tasar	30000	90000	900**	50000	2.80/cocoon	1.60:1

Production Technologies: Vanya silk productions totally depend on the host plants of the Vanya or non-mulberry silkworms. Initiatives taken by the central government's projects and schemes for the promotion of non- mulberry silkworm is the conservation of the food plants and identification of new host plants for silkworm, as the non-mulberry silkworms are mostly polyphagous insect, that feeds on more than one host plants. Second, experimenting with a different method of raising non-mulberry silkwormsthat is, in a controlled environment-since rearing tasar and muga silkworms outdoors in the wild causes more instability in their ability to produce silk because of the effects of the climate and the proximity of insect infestation.

Another way of promoting Vanya silk is training and extension services to farmers. In the state of Karnataka, India, the Central Sericultural Research and Training Institute (CSR&TI) implemented a group approach to promote technology adoption among sericulture farmers. The focus was on empowering rural women by forming sericulture women groups (Geetha and Rao, 2016) [9]. Collaborating with research institutions, universities, NGOs, and private sector entities to enhance the scope and impact of sericulture development. Ensuring strong support from government agencies to provide resources, funding, and policy frameworks that enable effective sericulture development. Promoting Indian silk in international markets through trade shows, fairs, and quality certification systems. Addition of new reeling cum spinning machine named Unnati reeling and spinning machine with the following features

- Fully solar powered
- High quality twisted yarn
- Can make yarn for warp and weft
- Safe and light-weight
- Can Reel, Spin and Twist Silk
- Useful for Tassar, Eri & Muga silk yarns

These all helps in promoting vanya silk promotion and helps diversifying sericulture sector in non-traditionalareas.

Swot Analysis

Strength	Weakness	Opportunity	Threats
Low capital and good returns Short gestation Women friendly occupation Ideal programme for weaker section of society	Inadequate market accessibility poor linkage Gap in technology transfer and extension support Poor linkage with other sectors Inadequate extension services shortage	Huge potential to create more employment Scope of value addition and product diversification Introduction of new technology to reduce labour input Adoption of village / panchayat training	Extreme climatic condition in specific regions and seasons Falling international prices and heavy dumping from chins at low prices Lack of awareness in domestic market Rural population is migrating fromfarm to urban areas

Case Study

Author	Year	Outcome
Kumbhar *et al*	2007[16]	Non-traditional rearing of temperate tasar silkworm (*Antheraea proylei*) in Kolhapur district of Maharashtra using *Terminalia catappa*in laboratory conditions showed 70% larval survival rate and increase in larval and cocoon weight, except the larval duration was same with that of outdoor condition.
YadavG.S.	2013[29]	Introduction of muga silkworm rearing in non- traditional area like Chhattisgarh on new host plant (*Litchi chinensis*) and suggested to give more attention and use of litchi as secondary host plant of muga silkworm.
Kavane R.P.	2014[13]	The rearing of the fagara silk moth *Attacusatlas* was done on *Terminalia catappa* under indoor rearing condition. A. atlas completed its life cycle from egg to adult within 62 days. Incubation period, larval (Six instars), and pupa period 10 days, 27.5 days 25 days respectively. The findings of *Terminaliacatappa* as a potential new host for fagara silkmoth *Attacus atlas* silkworm has opened new vistas in promoting vanya silk.
Kumar *et al*	2015 [14]	Successive trials in 2011-12 and 2012-13 reveal that Bageshwar can be a potential area for Muga culture. Hence the crops namely Jestha, Bhadra and Kartika are most conducive for muga culture in Bageshwar.Moreover, it will be helpful to boom the economy of the local farmers and entrepreneur.
Gupta R. K.	2024[10]	In order to revive the interest of silkworm rears the Division of sericulture SKUAST, Jammu took initiative to work on year- round rearing practices with the non-violent Eri silk varieties in Jammu region with about 5 crops per year.
CSB, Ministry of textiles	2024[20]	An initiative to encourage castor-growing farmers in Gujarat, the Central silk board, Minister of Textile, Government of India launched the project at SardarkrushinagarDantiwadaAgricultural University and Kalyan Foundation in Palanpur.

Future Prospects

1. Diversification of sericulture in northern states of India that are already practicing sericulture.
2. Exploring new products such as silk yarn, silk fabric, and silk blends to diversify the market and create new revenue streams.

Conclusions

- The production of silk in North India, especially Vanya silks (muga, eri, and tasar), has a lot of promise but is currently underdeveloped because to issues including poor infrastructure, a lack of facilities for storage and transportation, and limited market access.
- The effects of climate change, price volatility, outbreaks of silkworm disease, and competition from low-cost synthetic fabrics are some of the major issues facing sericulture producers that impede the industry's expansion.
- In order to improve the livelihoods of rural populations engaged in silk production, the Indian government has launched a number of projects, such as "Silk Samagra-2," to advance sericulture through research, technological transfer, and market development.
- Increasing production and giving farmers access to new revenue streams require diversification tactics including investigating new products and incorporating Vanya silk production into agroforestry schemes.
- The value of working with academic institutes and non-governmental organizations, as well as providing farmers with extension services and training, in order to encourage sustainable practices and improve the overall sustainability of the North Indian silk sector.

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