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Scope for Region and Season Specific Mulberry Silkworm (*Bombyx mori* L) in Temperate Regions of Jammu and Kashmir

Kiran Rudramuni*, Bharath Kumar Neelaboina, Shivkumar, Mir Nisar Ahmad and Sukhen Roy Chowdhury

Silkworm Breeding and Genetics Section,

Central Sericultural Research and Training Institute, Central Silk Board, Pampore - 192 121, Jammu and Kashmir

***Corresponding author:** **Scientist B, Silkworm Breeding and Genetics Section, Central Sericultural Research and Training Institute, Central Silk Board, Pampore - 192 121, Jammu and Kashmir**

e-mail: **kiranrmv1990@gmail.com** **Contact:** **+91- 6005755493**

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ABSTRACT

The silkworm, *Bombyx mori* is an important economic insect for its production of silk, aptly named as the queen of natural fibres. Silkworms are classified into Japanese, Chinese, European, Korean and tropical races based on their geographical origin. The difference in the adaptability of silkworms for different regions and seasons has been studied and documented in several studies. China and Japan have achieved remarkable breakthroughs in silk production by evolving highly productive silkworm races suited to the local conditions and agronomical practices. This review is an attempt to introduce the reader to mulberry sericulture in temperate and tropical regions, role of environment, performance of some popular silkworm breeds upon relocation, followed by details of authorized region and season specific silkworm breeds of China, Japan and India and special emphasis on scope for region and season specific silkworm breeds in temperate regions of Jammu and Kashmir.

Key words: Sericulture, Environment, Adaptability, China, Japan, India

The silkworm, *Bombyx mori* L (Lepidoptera: Bombycidae) is an insect of great importance for its production of silk, aptly named the queen of natural fibres (Chauhan and Tayal 2017). This unique lepidopteran insect completes its life cycle while engineering an economically distinct structure made of silk called cocoon (Fan-Sun *et al.* 2018). The lepidopteran species have been reared for silk production for more than 5000 years (Nagaraju and Goldsmith 2002). Since then, silkworms have undergone many evolutionary changes due to natural as well as manmade selections after several thousands of generations, thereby creating a wide genetic diversity (Jingade *et al.* 2011). Subsequently, silkworm breeding programme which heightens the production capability has been given importance. From a commercial point of view, the main objective of silkworm breeding is to gradually improve traits of economic importance and to increase the profits of the sericulture industry (Mirhosseini *et al.* 2012).

Mulberry sericulture in temperate countries

Silkworms are classified into Japanese, Chinese, European, Korean and tropical races on the basis of their geographical origin. During the process of distribution, the silkworms got adapted to the particular environmental conditions of the respective regions. Further, silkworms are classified as univoltine, bivoltine and polyvoltine on the basis of difference in the voltinism. Voltinism in silkworms tends to be influenced by environmental conditions where univoltines are suited cold regions, bivoltines for warm and polyvoltines for tropical regions (Yoshitake 1970, Otsuki and Sato 1997, Kosegawa *et al.* 2000, Chauhan and Tayal 2007). Among these geographical origins, temperate origin silkworm produces a higher quality of silk, whereas the silkworm from the tropical origin is hardy and tolerant to diseases (Zanatta *et al.* 2009). Likewise, temperate countries like Italy, France, Japan and China are known for superior quality silk (Pal 1930). Majority of the silk production in China and Japan is done in temperate regions. The availability of favourable temperature regime and nutritive mulberry leaves that sprout in spring after severe winter are congenial for quality silk production (Narayanan and Tikoo 1969, Goldsmith *et al.* 2005, Chauhan and Tayal 2007).

Mulberry sericulture in India

India is the second largest cocoon-producing country in the world only next to China (Takeda 2009, Singh and Kumar 2010). Sericulture in the country prospers predominantly under tropical regions with marginal subtropical and temperate regions. In India, sericulture suited to each of its region is practiced to suit the varied agro-climatic conditions (Takeda 2009, Sajgotra and Bali 2016). Multivoltines and hybrids of multivoltine and bivoltine are mostly reared in tropical regions (Karnataka, Tamil Nadu, Andhra Pradesh, West Bengal) and bivoltines are reared in subtropical regions (Himachal Pradesh, Uttar Pradesh, Uttarakhand, Punjab, North-Eastern states, Jammu) and temperate regions of Jammu and Kashmir (Takeda 2009, Kumari *et al.* 2011, Sajgotra and Bali 2016, Dar *et al.* 2017).

Silk production in India has increased sharply in recent years (Takeda 2009). However, sericulture in India suffers from inherent problems in the production of quality silk. In reference to China, the quality of silk from India is poor. Import price of Chinese bivoltine silk is lower than the price of Indian bivoltine as well as multivoltine silk. Thus, reelers prefer imported Chinese bivoltine silk over Indian silk (Kumaresan 2002).

Mulberry sericulture in temperate regions of Jammu and Kashmir

Countries such as China and Japan have achieved a remarkable breakthrough in the production of silk by evolving highly productive bivoltine silkworm races suitable to the local conditions and agronomical practices (Yokoyama 1979). In India, Jammu and Kashmir is the only traditional sericulture belt which share the same altitude as the leading silk producing countries of the world (Ali 2015).

In the past, Kashmir was one of identified regions in country where seeds from France and Italy met fair amount of success along with Dehradun and Mysore (Pal 1930). Further, attempts towards import of exotic bivoltine or univoltine races from other countries such as Russia, Japan, China, and Iran were also successful in Kashmir area (Muniraju and Mundkur 2018). The topological status of the region has an edge over the other states for its high-quality bivoltine silk production. Sericulture experts of Japan have recognized the superiority of the favourable climatic conditions for the production of high-grade raw silk of international standard (Kamili and Masoodi 2000, Ali 2015, Dar *et al.* 2017). According to Narayan and Tikoo (1969) Kashmir has favourable climatic complex for sericulture even better than Japan.

Kashmir was a suitable cradle for sericulture. Mulberry trees were worshipped with a sort of reverence in the area. However, much like the case of France and Italy, due to the import of pebrinised seeds, Kashmir sericulture got decimated. The ‘Kashmir race’, a productive indigenous univoltine race was lost due to the outbreak of Pebrine (Mukherjee and Gautum 1993, Kamili and Masoodi 2000). Lately, sericulture in the region is characterized by low productivity and higher cost of production (Malik 2009). This can be largely attributed to the lack of productive silkworm breeds/hybrids suitable for agro-climatic conditions of the state (Trag *et al.* 1992). According to Tazima, a eminent Japanese sericulturist "Basically Kashmir sericulture suffers for want of its own races of silkworms" (Tazima 1958 cited by Narayan and Tikoo 1969).

Role of environment

In India, successful rearing of bivoltine races in tropical regions was not possible until 1970s (Kumaresan 2002). Breeding experiments using Japanese commercial hybrids as breeding resource material initiated thereafter at Central Sericultural Research and Training Institute, Mysore resulted in hardy bivoltine races suitable for tropical conditions (Singh and Kumar 2010). The introduction of hardy characteristics of tropical race into the temperate race leads to the development of promising breeding materials for further improvement. However, temperate sericulture differs from tropical due to the distinctive seasonal variations in comparison to tropical. In tropical conditions, seasonal differentiation is not marked and sericulture is practiced throughout the year and up to six cocoon crops are harvested annually. Whereas in temperate conditions there are only two main cocoon crops from spring and autumn seasons (Iyengar 1998, Chauhan and Tayal 2007). The better performance of a race during certain seasons of a year heralds its better adaptability. As pointed out by Barton (1986), the evolved breeds were subjected to fluctuating agro-climatic conditions so as to retain polygenic resistance to unfavourable climate.

Development of alternative seasonal phenotypes according to the environmental changes are reported in many insects (Sato *et al.* 2014). The impact of environmental factors such as biotic and abiotic factors is of vital importance for the success of the sericulture industry. It is well known that most of the traits of economic importance in silkworm are quantitative in nature. The quantitative characters of economic importance include cocoon weight, shell weight, shell ratio and filament length. The phenotypic expression of these characters are significantly influenced by genes as well as environmental factors such as temperature, relative humidity, light and nutrition (Kogure 1933, Miyagawa and Sato 1954, Legay 1958, Takeuchi 1959, Ueda and Lizuka 1962, Suzuki *et al.* 1962, Yokoyama 1963, Arai and Ito 1963, 1967, Horie *et al.* 1967, Zhao *et al.* 2007, Rahmathulla 2012). Genes being the endogenic factor plays a major role and environment act as an exogenic factor for the gene expression. As a result, the same genotype can produce altered phenotype according to the environment (Zhao *et al.* 2007). Thus, congenial environment becomes necessary for optimal expression of genotype (Muniraju and Mundkur 2018).

Therefore, it becomes imperative for silkworm breeders to evolve region-specific breeds/hybrids as one of the main objectives to minimize the risk of falling below a certain yield level. In order to accomplish this objective, it is essential to identify the suitable parental material by evaluating the breeds. Identifying gives a deeper insight with respect to their genetic endowment determining the productivity and adaptability for their effective utilization.

Region specific silkworm breeds

The difference in the adaptability of silkworms towards different regions and seasons have been identified by sericulturists of China, Japan and South Korea (Hirobe and Ooi 1954, Yokoyama 1976, Kui *et al.* 1990 cited by Mary *et al.* 2012, Thiagarajan *et al.* 1993a). Consequently, these countries have achieved a remarkable breakthrough in the production of silk by evolving highly productive bivoltine silkworm races suitable to the local conditions and agronomical practices (Yokoyama 1979).

China has identified several silkworm breeds for different regions. For example Qingsong × Haoyue, Su 5 × Su 6, and Chunlei × Zheuzhu are the identified commercial breeds for areas along Yangtze River. Similarly, Qingsong, Haoyue, Sufang, Chunhin, Chunhin × (Zhongzhu), (57A × 57B) (24 × 46), Zhelei × Chunhin, Furong × Xianghin, Haunghe × Keming for tropical zone, Hua He (Ch) × Tong Fei (Jap), Su 16 (Jap) × Su 17 (Jap) for Sichnan, Zhejiang and Jianggsu provinces and Tung- 34 (Ch) × Su- 12 (Jpn), multivoltine races Nan Nung -7, Guangdong 3, Guangdong 4 for Guangdong province (Reddy 2005a).

Silkworm breeding in Japan achieved remarkable success mainly due to the rearing of native temperate silkworm breeds. Korea, which also shares temperate climatic conditions benefitted from the usage of Japanese technologies for higher silk productivity (Nagaraju 2002). In Japan, authorization of breeds takes place separately for spring, and summer- autumn. However, there is no separate region wise breed authorization in Japan (Iyengar 1998).

On the other hand, silkworm races cultured outside their native congenial environmental conditions resulted in changes in the traits of economic interest. It has been reported that over the period of time they behave like a polyvotine, with observable loss in their productive qualities. For example, temperate race *C. nichi*, a Chinese × Japanese hybrid upon relocation to tropical conditions resulted in loss of productive traits to retain its survivability. Further the race lost its hibernating character and has transformed into a multivoltine race with high adaptability to tropical conditions (Kumar and Reddy 1998, Nagaraju 1998, Muniraju and Mundkur 2018). The changes in the traits of C. nichi is comparable with the experimental results from Shibukawa (1965) and Nagaraju (1990) (Cited by Nagaraju 1998). The experiments by the authors involved rearing of silkworms at different temperature regimes, where authors opine that viability gets improved with the increase of temperature but at the expense of cocoon weight.

In silkworms, it is observed that survival is negatively correlated with the silk content (Iyengar 1998). Inexplicably, this correlation is caused by genetic and environmental factors which effects the correlation between genotypic values of the two characters and correlation between the environmental variations (HoZoo 1997 cited by Muniraju and Mundkur 2018). Based on the 15 years of breeding data, Nagaraju (1998) opines that productivity is correlated with survivability.

In another instance, upon relocation of multivoltine silkworm Pure Mysore to temperate conditions, an increase in cocoon weight was documented, when compared to its performance in tropical conditions. However, the increase in the productivity was not up to the performance of a temperate bivoltine. This is due to the interactions between genotype and environment causing these geographical ecotypes to have their own optimum means (Nagaraju 1998, Muniraju and Mundkur 2018). These observations indicate that native silkworm races that evolved under particular environment holds an advantage over relocated silkworm races.

Season specific silkworm breeds

Cocoon yield being an important phenotype, is influenced by both genotype and environment (Sudha *et al.* 2007, Zhao *et al.* 2007). The best cocoon crop (both quantitative and qualitative) can be obtained in season with environmental conditions most favourable for its genotype (Thiagarajan 1993a). Morohoshi (1969) reported that the genotypic differences among the races due to variable gene frequencies at many loci make the respective races to respond differently to changing environmental conditions. Thus, development of silkworm breeds specific to the particular climatic condition should be of great interest. The need for region or season specific races arises mainly due to the variation in seasonal and geographical variations and quality of the feed (Iyengar 1998).

As observed by Narayan and Tikoo (1969) and Zhao *et al.* (2007), mulberry leaf that sprout in spring after winter and weather conditions are favourable for quality silk production. Whereas in summer and autumn seasons, profound changes in the temperature, humidity and poor leaf quality affects the quality of silk. In silkworms, it is observed that survival is negatively correlated with the silk content. Thus, the breeds with higher silk content are preferred for spring and breeds with better survival are preferred for summer and autumn (Iyengar 1998).

In an attempt to evaluate the season specific performance, Thiagarajan *et al.* (1993a) reared twenty six strains of silkworm in spring, summer, and autumn seasons. The economic traits like cocoon yield, single cocoon weight, single shell weight, shell ratio, and filament length were noted in the study. The authors report that results of analysis of variance indicated significant variation at 1% level among twenty six strains between seasons in all the five character studied. Similar results have been reported by Pillai (1979), Pershad *et al.* (1986), Thiagarajan *et al.* (1993b) (Cited by Thiagarajan *et al.* 1993a). In a study by Gangwar (2012) on effect of environmental factors on silkworm efficiency, the author report that breeds studied in the experiment were well-suited for spring and autumn season in comparison to summer. Similarly Seidavi (2010a, 2010b) found that season of the rearing had a substantial effect on silkworm function.

Observing the importance of seasonal differences, researchers from China have evolved suitable silkworm breeds for spring, summer and autumn. The breeds includes, Qingsong × Haoyue, Su 5 × Su 6, Chunlei × Zheuzhu and Suhua × Chunhui for spring, Hua He (Ch) × Tong Fei (Jap), Su 16 (Jap) × Su 17 (Jap) and Fangshan × Xing for autumn, 57A·57B × 24·46, Tung 34 (Ch) × Su 12 (Jpn) and 873 × 874 for spring and autumn, and Furong × Xianghui, Feng 1 × 54A, Zhongqiu × Jinling, Xuhua × Quixing, (Su 3. Qiu3) × Su 4, 317 × 318, 415× 416, Fengyi × 54A Xuhua and Quixing for summer-autumn (He *et al.* 1998 cited by Zhao *et al.* 2007; Iyengar 1998; Zhao *et al.* 2007; Reddy 2005a). Further, Chinese researchers have also evolved races such as adversity-resistant, hypersilkgeneous varieties and fluoride-tolerant variety according to the seasons (Zhao *et al.* 2007).

India is not lagging behind in identifying hybrids for different states and seasons. In 1995, Central Silk Board under race authorisation programme identified YS 3 × SF19, SH 6 × KA, SH 6 × NB4D2, Skuast 1 × 6 for spring, CA 2 × NB4D2, CC1 × NB4D2, PAM 111 × SF19 for autumn/ early winter of Jammu and Kashmir. Further in 1999, the board authorized CSR 2 × CSR 4, CSR 2 × CSR 5, CSR 3 × CSR 6 for spring/ autumn for temperate conditions (Reddy 2005b). Lately, farmers in temperate conditions of Jammu and Kashmir are using CSR double hybrids.

Similarly, numerous season specific breeds have been authorised in Japan. This includes 19 silkworm strains suitable for spring season, 22 for summer and autumn seasons (Shimizu and Tajima 1972 cited by Thiagarajan 1993a). In Japan, the authorised season specific breeds are available for both natural as well as artificial diet (Iyengar 1998). For more details on the authorised season specific races from Japan, the readers may refer to Otsuki and Sato (1997), Iyengar (1998).

Mulberry sericulture in India thrives under diverse eco-climatic conditions ranging from temperate to tropical. Differences in climatic conditions of different regions across the country, including the significant distinctions in temperature and humidity determine many important phenotypic characteristics of the silkworm. According to quantitative genetics theory, two or more individual genes and their interactions along with the environment determine several phenotypic characteristics. Most of the important economic traits in silkworm such as fecundity, silk content and resistance to diseases are quantitative in nature (Nagaraju and Goldsmith 2002, Zhao *et al.* 2007).

Thus, in order to improve the earnings of farmers, development of silkworm breeds suited to particular seasons and agro-climatic regions becomes necessary. The silkworm races maintained under germplasm programme composing silkworms of temperate countries could be useful for evolving new hybrids for temperate regions of Jammu and Kashmir. While considering the success of China and Japan under temperate regions, emphasis on the region and season specific races could drastically improve the gap in quality silk from India.

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