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Mechanization in Sericulture: An Overview

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Sericulture is a labour-intensive enterprise involving activities with dependency on manual labour. With the growing competition of Chinese silk which is of superior quality and lesser price, the indigenous silk is falling in demand in the domestic market. There is a felt need to reduce the cost of production to improve the quality of Indian silk and its value. This can be achieved through mechanization in the various steps involved. For instance Tractor-operated mouldboards or disk plough and Tractor-operated Auger Digger for raising of plantations reduce labour cost to a considerable extent. Power-operated Sprayers for disinfection of rearing houses increases efficiency and also ensures good harvest of crop. Mechanisation of post cocoon sector for cocoon stifling, cocoon cutting and for silk reeling and spinning have improved quality, increased productivity thus reduction in prices. Mechanization will not only reduce drudgery and dependency on labour but also enhance the quality of life. Mechanisation thus culminates to lessening the cost of production.

Keywords: Sericulture; Indian silk; mechanization; cost of production; cocoon yield.

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1. INTRODUCTION

Sericulture is derived from the Latin word "Serio" or the Greek word "Sericos" implying "Silk" and "Culture," and the English word signifying "Raising" adverts to the "raising of silk creating living beings" with the end goal of acquiring silk from them [1]. Thus, Sericulture is the activity of raising silkworms, including the composite action of raising and maintaining the nourishment plant of the silkworms, to form a protective covering called cocoon and reeling/spinning of the cocoons to obtain the end product, silk. The post-cocoon sector includes silk reeling, spinning, twisting and weaving [2]. The harvested cocoons are used for silk reeling, or, in other words, the process of removing threads from the cocoons. All these steps play an important role as they establish the features and quality of the silk thread. The Indian Silk industry is differentiated into mulberry silk and wild or vanya silk, comprising Eri Silk, Muga Silk, and Tasar Silk. While the Mulberry, Muga and Tasar silk threads are obtained from the reeling process, the Eri spun yarn is obtained from the process of spinning as Eri cocoons are open-ended and cannot be reeled [3]. It can thus be stated that silk production is an arduous task that is best reflected in the Chinese adage "Tolerance is power, with time and persistence the mulberry leaf turns into a silk outfit." Silk is a highly valued natural fiber and frequently referred to as "ruler of material" as it possesses characteristics that no other fiber can co-ordinate. Its luster, elegance, durability, delicateness and tensile properties are unmatched [1]. The Silk industry is a crucial component of the economy of developing countries because it provides a considerable source of income to the rural masses [4].

On an average, India earns over Rs 2094.42 crores every year in revenue by exporting various silk products [5]. Despite various technological advances over the years, such as high-yielding varieties of mulberry, productive races of silkworms, cost-effective silkworm rearing, and integrated pest and disease management technologies that have made it a sought-after activity among farmers, they still face stiff competition from Chinese silk. The main culprit is the high cost of Indian silk production. Chinese silk, which is not only of superior quality, is also available at lower rates [6]. What makes the cost of production of silk in India high is the fact that silkworm rearing and the associated activities are highly labour-dependent, which accounts for almost 65 to 70 % of the total cost of production [7]. Therefore, to face global competition with imported silk, efforts are required to reduce the cost of production and improve the quality of silk. Reducing the dependency on labour will not only reduce the cost of production but also improve efficiency and enhance productivity as most works in sericulture are carried out manually or with inefficient tools and equipment. In this regard, mechanization plays an important role [8]. Mechanization in agriculture and horticultural crops in India has already played a major role in improving land and labour productivity and reducing the cost of production [9]. Hence, in sericulture, mechanization could make it an attractive economic activity among farmers. The aim of this review paper is therefore to highlight the importance of mechanization in Sericulture and the various equipment and tools invented to reduce drudgery and improve the quality of life.

2. MECHANIZATION IN SERICULTURE

Mechanization can be defined as the science of the application of mechanical aids to increase the production and preservation of crops with less drudgery and increased efficiency [10]. Sericulture comprises two land-and two industrial-based activities. The rearing of silkworms and the raising of its food plants fall under land-based activities, whereas silk reeling/spinning, manufacturing, weaving, knitting, drying, etc. make the silk fabric of industrial nature. In India, most of the activities are traditionally carried out, such as silkworm rearing, cultivation of food plants, or egg production whereas in countries such as China and Japan, each step of silkworm rearing is highly mechanized. Profitability in sericulture is dependent on leaf and cocoon yield, the prices of cocoons, and the cost of food plantation cultivation and rearing expenses. Over the past few years, profits in sericulture have reduced substantially due to a sharp increase in input and operational costs. This makes it difficult to surmount the cheaper prices of Chinese silk and to make sericulture a lucrative venture for farmers with large landholdings. One way to thwart the rising cost of production is to improve labour productivity [6].

The cultivation and maintenance of silkworm food plants involves activities such as the preparation of land, pit digging, intercultural operations, nutrient management, pest and disease management, and irrigation. The sericulture crop cycle is 60-70 days long with 5-6 crops per year, making it a time-oriented enterprise [11]. The Indian silk industry has not

made the desired qualitative and cost-effective progress due to technological inactivity, and people are economically backward. With the changing times, the technologies have improved and silk reeling machines have also undergone many changes that have increased efficiency and reduced drudgery [12]. In India, labor expenses make around 60–70% of the entire cost of producing silk. Certain processes might be mechanized to reduce manufacturing costs and increase quality, giving Indian businesses a competitive edge against low-cost, high-quality imports [13]. Mechanization of sericulture not only reduces labour but also reduces the need to employ family members, especially children. There is alleged involvement of child labour in the silk industry which is a major concern [14]. Automation and mechanization in the post-cocoon sector are necessary for increased silk production and improving sericulture. Reductions in cost and time can be achieved through intervention with appropriate mechanical aids at different stages of production [6].

2.1 Mechanization in Host Plant Cultivation

India has the monopoly of producing all four types of silk i.e., Mulberry silk and Vanya silk (Eri, Muga, and Tasar). Raising and maintaining food plants is labour-intensive. For instance, approximately 800 man-days are required per year to maintain one hectare of mulberry garden, which could be reduced to 1/10th through mechanization [11]. The raising of any crop begins with the preparation of the land or tillage. Land should be well-prepared to ensure good aeration and supply of water and nutrients to the root zones. A tractor-operated sub-soiler is one such farm implement used for deep tillage. It breaks up and loosens the soil at deeper levels than ordinary plough and disc harrow. Land for new mulberry plantations can be prepared faster and at a lower cost using tractor-operated mouldboards or disk plough, cultivators, and harrows [8]. A worker manually makes 1,500–2,000 cuttings per day. With the help of the mulberry cutting preparation machine developed by CSRTI, Mysore 1, 400 to 1, 500 cuttings can be prepared in one hour. For the preparation of mulberry cuttings, a machine developed by CSR&TI, Mysore, if engaged, reduced the man-days requirement from 8 (eight) to 1 (one) [15]. The next step is the transplantation of healthy seedlings/cuttings into the pits. Tractor-operated Auger Digger can be employed to create pits (mainly used in the pit system of mulberry plantations) [8]. Power tillers, power weeders, and tractor-operated cultivators can be used for intercultural operations. Mechanization in intercultural operations reduces costs by 40-50%. Using a fertilizer applicator and drip or sprinkler irrigation systems also reduces man-days requirements. For uniform spraying of chemicals, one can use a self-propelled CSR&TI sprayer or ASPEE tractor-mounted sprayer [11]. Power-operated Sprayers can also be used in the application of chemicals for the disinfection of rearing houses. The timely control of diseases and pests is required for the production of healthy mulberry leaves. CSRTI, Mysore tested knapsack-type bush cutters for mulberry shoot harvest. About 600-800 kg of shoots can be harvested within one hour. Pruning and training are other activities that can be improved using mechanical tools. Manual drudgery can be reduced using a power-tiller-operated pruner [6]. The integration of GPS technology and sensors allows the precise mapping and monitoring of mulberry fields. This facilitates optimized resource utilization and data-driven decision making. Emerging technologies in robotics are being explored for tasks such as selective harvesting, which further reduces the dependency on manual labour.

Host plant cultivation is an important part of the sericulture industry. Good quality leaves lead to the production of good quantity and quality silk-rich cocoons. In recent years, the cost of leaf production has increased due to an increase in labour wages and the cost of inputs such as fertilizers and water. Nearly, 60 -70 % of the cost of producing silk cocoons is used for the production of mulberry leaves. In mulberry leaf production, over 65-70 % expenditure goes for labour wages for intercultural and other operations [6]. Hence, the cost of mulberry leaf production must be reduced to reduce the cost of silk cocoon production. Appropriate mechanization through the adoption of tools, equipment, and machines for land preparation, cutting preparation, intercultural operations, chemical spraying, and shoot harvesting can reduce the cost of mulberry leaf production by at least by 35-40 %. Hence, the cost of silk cocoon production can be reduced by at least 25–30 % through appropriate mechanization in most mulberry cultivation activities [11]. The use of Machine Learning Techniques to forecast the yield of mulberry crops based on soil factors help farmers to make informed plans to predict the potential yield their land can generate [16]. Moreover, mechanized mulberry cultivation will

enable farmers to expand the area under mulberry, so they rear more silkworms.

2.2 Mechanization in Silkworm Rearing

Silkworm rearing accounts for 40% of expenditure as labour wages in activities involving cleaning and disinfection of rearing houses, leaf chopping or plucking, bed cleaning, cocoon harvesting, deflossing, and sorting [7]. Rearing house/grainage house disinfection is one of the most important steps in ensuring a good crop. Instead of using hand-operated gator sprayers, which have low delivery pressure and are suitable for dwelling houses and small rearing houses, it is better to use power sprayers with effective high-pressure delivery. The young age silkworm Dusting machine and battery-operated duster designed by CSR&TI, Mysore not only reduces the chances of health hazards but also increases efficiency as more trays can be dusted in a short span [11]. A prototype developed for the implementation of sericulture farm automation using sensor network and GSM Technology, which is advantageous in increasing silk production [1]. The application of Internet of Things (IoT) to link devices and collect data is widespread. A system was designed to remotely assess and gather information of abiotic parameters including temperature, humidity and the buildup of hazardous gases can be utilized to automate the climate within the enclosed space such as a rearing house or grainage. Additionally, diseased worms were identified by image processing [17]. Prototype designed based on multi-sensor system via image processing and support vector machine for gender-based classification of silkworms while still in the cocoon stage has promise for increasing the efficiency of grainage facilities where gender classification is done manually. It revealed a maximum accuracy of 93.54% and 88% repeatability, suggesting suitability for use in industrial settings [18]. Automation by use computer technologies such as Artificial Neural Networks, IoT, Artificial Intelligence approaches and Image Processing Algorithms reduces the need for additional physical labour and eliminates human error [19]. In muga silkworm rearing, for cocooning use of box-type bamboo mountages (fabricated by CMER&TI, Lahdoigarh) saves labour by up to 60% and reduces space requirements [15].

2.3 Mechanization in Post Cocoon Sector

The silk industry in India has a huge potential, and recent developments have been made to utilize machines in various sericulture operations to improve productivity. Post-cocoon activities start with the harvesting of cocoons and end with the extraction of silk fiber [20]. Each step is sensitive and time oriented for the production of quality silk. In advanced countries such as China and Japan, the efficiency of labour is quite high because of the availability of efficient machines. In India, the silk industry is more or less dependent on manual operations; therefore, quality is not that which can compete with the global market. However, this sector is not devoid of mechanical progress. Over the years, rapid technological developments in this sector have reduced drudgery.

The post-cocoon sector comprises various steps, such as cocoon testing, cocoon stifling, storing of the cocoons, cocoon sorting, cocoon cooking, brushing, reeling, re-reeling, lacing, skeining, book marking, raw silk testing, and grading. When ripened, silkworm larvae are mounted on mountages to spin their silken cocoons. Central Silk Technological Research Institute (CSTRI) Bangalore has developed hand-operated and pedal-operated harvesters that speed up operation [6]. Mulberry cocoons are mostly harvested using these harvesters. Cocoon drying is highly specific and time-sensitive process. If the cocoon is not dried promptly, the cocoon quality can be damaged either by the steaming-hot phenomenon or by the emergence of moths damaging the cocoon layers and rendering the cocoon shell useless. Stifling is the killing of pupae without damaging the cocoons. Cocoons can be stifled by sun drying, which is dependent on environmental vagaries. Sun drying is a simple and inexpensive method that is cumbersome and unsuitable for modern reeling. Other methods are steam stifling and barrel steaming which only kills the pupa but does not dry it. The use of Hot Air Dryer fulfils the twin objective of killing the pupa and fully or partially drying it. Electrical Hot Air Dryer machines are in use. Electrical drying of muga cocoons has shown favourable results in terms of raw silk recovery and reeling waste. Moreover, CMER&TI, Lahdoigarh has fabricated a machine for stifling and drying of muga cocoons which works on the hot air-drying principle and using locally available fuels like firewood [15]. CSTRI Automatic Tasar Cocoon Sorting Machine is a user friendly machine which separates the cocoons in a systematic manner with a separating capacity of 40,000 to 50,000 cocoons in an hour and 99% accuracy. The machine addresses the limitations faced during manual

separation of cocoons [21]. Floss removal is an important process which is mostly done manually and time consuming. Recent developments have introduced hand operated, hand operated cum motorized and fully motorized deflossing machines. To remove floss, hand-operated and motorized deflossers are available which defloss about 500 kgs/day where manually only 10kgs/day could be removed [11]. Cocoon cutting machine with efficiency of cutting 5000 cocoons/hour have been developed [22].

Mulberry silk is reeled using charkhas, cottage basins, multi end reeling machines or automatic reeling machines. Multi end reeling machines are an improvement over cottage basins as it facilitates production of bigger lots of superior raw silk quality ensuring better productivity and higher returns for reelers [23]. Charkha reeling device is a crude contrivance with minimum mechanization and generally engaging child labour. Motorization of charkha is improvement of this contrivance and dissuading child labour. Central Silk Technological Research Institute (CSTRI), Bangalore has developed a Tasar/Muga Reeling-cum-Twisting Machine (THRTM) to discourage the traditional practice of thigh reeling by the women weavers. The machine is suitable for reeling and twisting of Tasar and Muga cocoons and helps in removal of drudgery involved in the traditional system [24] .Muga cocoon is reeled on “Bhir” which is a traditional reeling device. Bhir devices have quality and productivity issues apart from being low income generating practice. Sonalika reeling machine developed by Central Silk Technological Research Institute can produce 1 kg muga silk yarn in 4 man days. Another machine called BANI- a weft reeling machine fabricated by CMER &TI, Lahdoigarh have productivity of 120-140 g silk yarn per day [15]. For the spinning of eri silk, different types of mechanisms are used such as hand spinning, CSTRI pedal cum motorized spinning and mill spinning. Takli and Charkha are hand spinning appliances but are disadvantageous as the process is not continuous and taxing on the spinner as it requires constant use of both hands. N.R. Das type charkha and Choudhury type Charkha machines are foot operated and production time was increased. CSTRI pedal cum motorized spinning machine produces yarn better quality to other hand spinning machine [25].

3. CONCLUSION

Mechanization in sericulture industry is the need of the hour to counter the menace of imported silk which is available at reduced prices apart from being superior in quality. Many technological advances have taken place in sericulture but a lot needs to be done in reducing the cost of production of silk cocoons, a major share of which is occupied by labour cost. Sericulture is part of our rich cultural heritage and preservation of this traditional craft is only possible if we adapt to technologies, sustainable practices, modern tools and machinery while enhancing productivity, sustainability and quality. Mechanization reduces cost and drudgery, improves efficiency, reduces time consumption in activities, and overall improves the working environment and better quality of life.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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