Chapter 2

Automation in Silk: Revolutionizing Sericulture with Technology

Wisdom Leaf Press
Pages number, 7–12
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https://journals.icapsr.com/index.php/wlp
DOI: 10.55938/wlp.v1i4.157

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Abstract

This book chapter looks into sericulture's revolutionary impact in empowering women and promoting sustainable livelihoods in rural areas. It examines the economic, social, and environmental aspects of sericulture, emphasizing its potential for money production, skill development, and community participation. The chapter additionally looks into sericulture's sustainable methods, which help to protect the environment and strengthen local economies.

This article examines technical breakthroughs for rejuvenating the silk industry, with an emphasis on current mulberry rearing techniques, biotechnology pest and disease control, and government regulations that promote environmentally friendly technologies. It also emphasizes automation and mechanization's possibilities for productivity and sustainability. The article explores case studies of effective technology and sustainability integration in sericulture, assesses the environmental impact of conventional methods, and makes policy recommendations for sustainable sericulture, with a focus on public-private partnerships. Silkworm diseases, such as Grasserie, can result in 30--40% output reductions. These illnesses can be identified through a variety of scientific approaches and laboratory processes. This article discusses sericulture methodologies, silkworm types and life cycles, current disease detection methods, the need for non-invasive methods, existing method limitations, and the revolution of deep learning, specifically Convolutional Neural Networks (CNNs), in disease detection systems and sericulture byproducts. Plant genomes may be quickly sequenced thanks to high-throughput sequencing methods, which also identify genetic markers associated with desired traits. Breeders are able to more accurately and efficiently select particular traits as a result. There is great potential for improving quality and productivity with mulberry genomics. Researchers can ensure a prosperous and sustainable future for sericulture by figuring out the molecular mechanisms that control development and use that knowledge to direct breeding initiatives

Keywords

Entomology, Sericulture, Silkworm Rearing, Manual Sericulture Management, Sericultural Science

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1. Introduction

The importance of insects in ecology, agriculture, medicine, and the pharmaceutical industry has led to a great deal of research on the subject of entomology. Two of the most studied insects are silkworms and honeybees because of their adaptability to a wide range of habitats. As model organisms and bioreactors, silkworms are useful in the medical field and pharmaceutical sector. In order to improve production and agricultural sustainability, genome editing techniques are being used to improve honeybees, the main pollinators of crops and wild plants, which face difficulties [1]. Sericulture, which primarily consists of the production of food plants to feed silkworms, such as domesticated Bombyx Mori, is a significant agricultural technique in the silk industry. Modern farming operations are mechanized, yet environmental stewardship remains a major concern. Temperature, humidity, air circulation, brightness, and chemicals involving carbon dioxide and smoke can all have an impact on embryonic development in silkworms [2]. Sericulture provides individuals with a steady source of income, allowing them to support their families and communities. It gives them control over resources, decision-making, and leadership positions. Women can improve their marketability by learning skills including mulberry farming, silkworm breeding, and silk production. Sericulture encourages environmentally beneficial farming techniques, which contribute to environmental protection and biodiversity. Sericulture participation also generates business chances for silk goods [3]. With sericulture making up the majority of its GDP, India is a major producer and consumer of silk. Growing food plants and silk cocoons and weaving them into textiles is known as sericulture, and it is a significant economic activity. Production declines of 30–40% can be caused by silkworm illnesses, particularly Grasserie. Numerous scientific strategies and laboratory-intensive procedures are currently being used to diagnose these ailments, ensuring the long-term sustainability of India's silk industry [4]. The study found that rearing practices and environmental factors significantly impact the health and quality of silkworms. It highlights the importance of favourable conditions for silkworm development and the potential for modern technologies to boost silk yield. The study also explores the relationship between cocoon form and filament strength and nutrition, particularly the quality of mulberry leaves. The results underscore the significance of integrating cutting-edge technology with conventional sericulture methods to guarantee sustainable silk production [5]. A key plant in sericulture, mulberry, is being improved through genomics. Scientists are studying genes linked to critical metabolic functions in order to learn more about the mechanisms underlying growth and development. Rapid genome sequencing of plants is made possible by high-throughput sequencing technology, which also identifies genetic markers linked to desired traits. This genomics discovery opens the door to mulberry farming's use of genetic enhancement [6].

2. Revolutionizing Sericulture with Technology

The technique of raising silkworms to produce silk in response to climate, humidity, and light intensity is known as sericulture. Environmental circumstances have a significant impact on the growing of silkworms. Automation and the Internet of Things (IoT) are needed to upgrade outdated methods. For silk production to be improved, environmental conditions must be closely monitored. Improving silk production requires the integration of smart sericulture and the Internet of Things [7]. Significant influences on silkworm growth and development are caused by temperature, humidity, and light intensity. The IoT paradigm makes it possible for products to monitor and control these variables by establishing wireless connections through intelligent mobile devices. The auto-controlled actuators that help to maintain these conditions include sprinklers, heaters, and exhaust fans. The unique feature of this concept is the system that can use sensors to monitor these attributes [8]. Figure 1 below shows the perfect environment for IoT-assisted sericulture. The production and efficiency of silk farming can be significantly increased by integrating IoT. Traditional methods are constrained by environmental regulations and labor, particularly Manual Sericulture Management (MSM). Using IoT, the Seri-Farm Automation System (SFAS) provides silkworms with real-time health monitoring, automated feeding, and precise climate conditions. SFAS significantly improves the quality and quantity of silk produced in comparison to MSM [9]. Artificial intelligence (AI) is the technology used to create robots that are capable of thinking, understanding, and learning so they may form opinions based on past experiences. Digitization has made AI more relevant, and with the right development and application, it can revolutionize a number of industries. The production of tasar silkworm seeds using AI could improve human comfort and increase the use of tasar sericulture [10]. Biotechnological treatments, particularly genetic engineering and molecular biology, can improve processes, enhance yields, and overcome conventional challenges related to sericulture. The shift from conventional approaches to improved scientific understanding is critical for conservation and breed enhancement. Modern high-throughput technologies, especially allele-specific hybridization and DNA arrays, are replacing traditional gel-based procedures. Advances in Next-Generation Sequencing technology open up new possibilities to explore tasar silkworm genetics [11]. Contemporary biotechnology has created new opportunities for silk production, allowing for the diversification of the sericulture process. Techniques including marker-assisted selection and transgenic expression of foreign genes can be exploited to fully realize the silk industry's enormous potential. Probiotics and artificial silkworm feed can also help improve silk quality. Silk has also been employed for biomedical processes [12]. Seri-biotechnology and bio-nanotechnology are contemporary bioscience advancements that have created a substantial influence on worldwide sericultural science research. However, India is still in its early phases, therefore concentrating on creating technology to promote silkworm and host plant growth is critical. Seasonal fluctuations in host plant nutritional content and composition, influenced by weather, pests, diseases, and agricultural methods, have a substantial impact on silkworm development [13]. Gene therapy, nano-biotechnology, and transgenic technology are being utilized to solve problems related to silkworm production, including the development of transgenic silkworms with increased cocoon quality and volume. Silk's distinct properties, like strength, elasticity, biodegradability, biocompatibility, and mechanical resilience, make it an important biomaterial for a variety of medical and pharmaceutical applications. Silk fibroin and sericin have high biocompatibility, manageable bio-degradability, and minimal immunogenicity [14]. Genome editing has expedited research and revealed promising application in sericulture, especially in breeding and treatment. CRISPR technology is a powerful yet fundamental technique in molecular biology. Genome editing techniques have been developed in silkworms, a model organism of Lepidoptera insects, which has aided research and may disclose novel mechanisms and targets in entomology and pest control [15]. Nanoparticles (NPs) have demonstrated potential in increasing mulberry cultivation and silkworm performance, notably in zinc oxide and iron oxide. These nanoparticles increased silkworm larvae's growth metrics, feed efficiency, and cocoon characteristics. They also increase silkworm reproduction, fertility, and resistance to illnesses involving BmNPV. TiO2, silver, and chitosan nanoparticles have antibacterial capabilities against silkworm pathogens, which contribute to inhibit illness transmission [16].

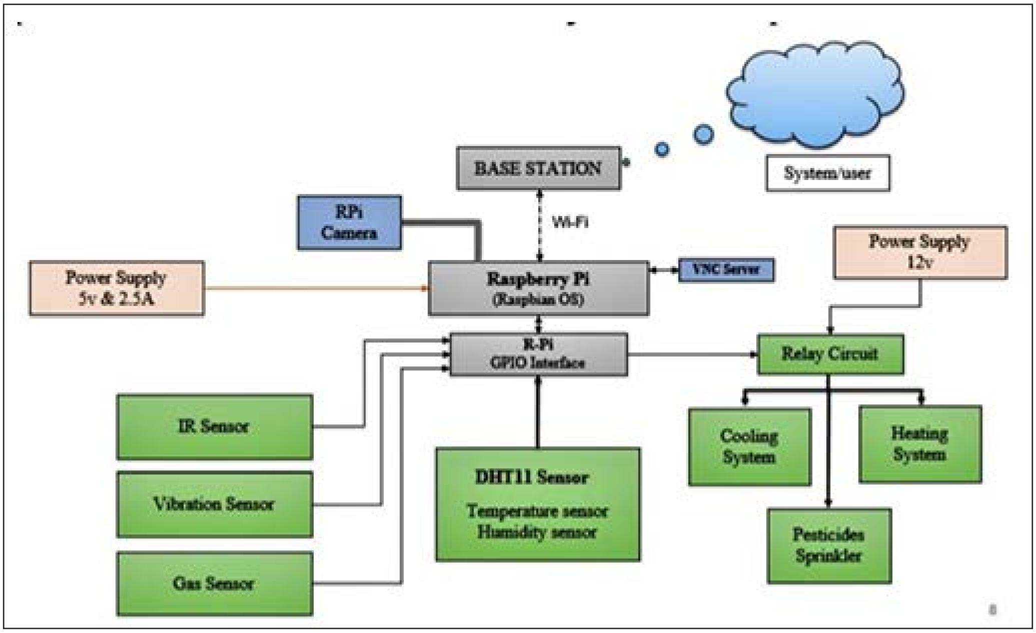

Figure 1. An Ideal IoT Assisted Sericulture Environment

3. Recommendations

Based on our thorough literature review on the current sericulture farming practiced across the globe, we propose the following recommendations.

- To stay competitive globally, the sericulture business must adapt to technological changes; failing to do so may have a severe influence on future production capacity.
- Promoting the use of silkworms in scientific research provides novel solutions and insights that benefit not only the sericulture industry, but also science and society as a whole.
- Micro-cocoons have the ability to deliver drugs such as alpha-synuclein in Parkinson's disease and ibuprofen in ocular illnesses. More research is needed to investigate the bioactive qualities of silk products and increase their socio-economic wellbeing.
- Climate control systems and automated rearing procedures are predicted to dramatically improve silk output and quality, transforming sericulture into a more sustainable and profitable sector.
- For silkworm health and productivity to be at their best, environmental stresses including temperature and humidity fluctuations must be controlled with the use of climate control systems and humidity regulation.
- Biotechnology has a huge impact on sustainable practices and innovation, thus incorporating sophisticated technologies into tasar sericulture is prospective.
- Scientific progress has been accelerated by the significant impact of bioscience on sericulture research. The diversification of products based on nanotechnology, sophisticated research on the negative effects of microbial bio-pesticides, and biotechnological solutions for sericulture-related

problems like host silkworm diseases and pests are still obstacles, though, and they are still in their infancy.

Conclusion

This study, in conclusion, emphasizes how important environmental conditions and contemporary raising techniques are to the physiology of silkworms and the caliber of silk produced. While cutting-edge technology like automated control systems and precise sericin curing processes greatly increase production efficiency, optimal temperature, humidity, air quality, and light exposure are crucial for optimizing silkworm health and cocoon quality. By combining these contemporary methods with age-old wisdom, silk consistency and sustainability can be enhanced, providing important information for sericulture's future. Transgenic technology was used to make silk filament, a double strand of fibroin joined by silk sericin, for pharmacological and therapeutic uses. Silk fibers are biocompatible, have no cytotoxicity, and disintegrate to non-toxic byproducts. Large-scale manufacturing of silk proteins for a variety of applications, including drug carriers, sensors, and tissue engineering scaffolds, has become possible because to technological advancements. Silk sericin, which is discarded by the silk industry, may be recovered and reused, and sericin can be extracted from silk in a variety of methods. Several countries are deploying artificial intelligence (AI) technologies to enhance productivity and gain data on product and marketing strategies. AI can quickly examine collected material and recognize patterns, giving businesses a competitive advantage. AI has the potential to increase its application in tasar silkworm seed production, but systematic research, planning, and execution are required to maximize its benefits. Tasar sericulture's biotechnological research aim to improve its practicality in the tasar silk production industry. These developments not only accelerate the industry to new heights, but also strengthen its resilience to environmental and economic challenges. Advances in DNA sequencing and analytics are hastening genomic research, making trait-gene association studies as straightforward as PCR amplification. However, bottlenecks such as germplasm evaluations, parental choices, progeny studies, characteristic introgression, and genetic engineering for mulberry development continue to exist, necessitating more study and breakthroughs in these areas.

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