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Posham Raghu Ram
M.Sc. Sericulture, Department of
Sericulture, Kakatiya University,
Warangal, Telangana, India

Innovative techniques in mulberry silkworm rearing: Improving yield and sustainability

Posham Raghu Ram

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Abstract

Sericulture, the art of raising silkworms for silk production, is a vital agro-based industry, particularly in many developing economies. Traditional silkworm rearing practices, while effective, often face challenges related to disease susceptibility, labour intensity, environmental control, and feed efficiency, impacting overall productivity and silk quality. Silkworm rearing has been a cornerstone of the sericulture industry for centuries, but with the advent of modern technology and scientific advancements, there is an increasing push to improve the efficiency, sustainability, and overall productivity of this process. Innovative techniques in silkworm rearing are essential to meet the growing demands for silk while minimizing the environmental impact. This paper explores cutting-edge methodologies and technologies that are revolutionizing silkworm farming, including the use of rain guns in mulberry plantation and integrated nutrient management practices. By incorporating these advancements, the silkworm rearing industry can not only increase yield and quality but also contribute to global sustainability efforts. Innovation has come up as technological solution to the sericulture problems along with being easy to learn, maintain and being cost effective. The aim of this paper is to present a comprehensive overview of these innovative techniques and their potential to transform the future of silkworm rearing.

Keywords: Sericulture, innovations, silk, technology, rain gun

Introduction

Sericulture is a science-based agro-industry that involves the cultivation of mulberry (*Morus* spp.), rearing of the mulberry silkworm (*Bombyx mori* L.), and processing of cocoons into raw silk. Among these components, mulberry silkworm rearing is the most critical and sensitive stage, as it directly influences cocoon yield, silk quality, and economic returns. The growth and development of silkworm larvae are highly dependent on precise environmental conditions, quality mulberry leaves, hygienic rearing practices, and scientific management throughout the larval and spinning stages. Traditional mulberry silkworm rearing practices, although widely followed, are often constrained by inadequate control of temperature and relative humidity, poor sanitation, high incidence of pests and diseases, and increasing dependence on manual labour. These limitations are further aggravated by climate variability, which adversely affects silkworm physiology, feed consumption, and survivability. As a result, sericulturists frequently experience low productivity, uneven cocoon quality, and economic instability.

In recent years, the development and adoption of innovative techniques in mulberry silkworm rearing have gained importance as effective strategies to overcome the shortcomings of conventional methods. These innovations focus on scientific regulation of microclimatic conditions, improvement of rearing hygiene, optimization of feeding schedules, and reduction of biotic stress. Improved rearing house designs with environmental control systems, use of advanced bed disinfectants, stage-specific feeding and spacing techniques, mechanized and improved mountages, and application of digital tools for monitoring temperature, humidity, and larval health have significantly enhanced rearing efficiency and cocoon quality. Rain gun irrigation is a modern water management technology that helps in uniform distribution of water over large areas. It reduces water wastage, saves labour, and ensures timely irrigation even during water scarcity. Proper irrigation through rain guns improves mulberry plant growth, leaf moisture content, and overall leaf quality, which are critical factors for healthy silkworm

Corresponding Author:
Posham Raghu Ram
M.Sc. Sericulture, Department of
Sericulture, Kakatiya University,
Warangal, Telangana, India

development and higher cocoon production. This technique is particularly useful in regions with irregular rainfall and limited water resources. Integrated Nutrient Management is another important innovative approach that focuses on the balanced use of organic manures, chemical fertilizers, and biofertilizers to maintain soil fertility and improve plant nutrition. In mulberry cultivation, INM enhances soil health, increases nutrient availability, and promotes sustainable leaf production. The use of farmyard manure, vermicompost, green manure, and microbial biofertilizers along with recommended chemical fertilizers helps in maintaining long-term soil productivity while reducing the environmental impact.

The incorporation of eco-friendly practices, biological agents, and precision sericulture approaches has been shown to improve larval metabolism, cocoon parameters, and silk filament characteristics while ensuring environmental safety. These advancements are essential for meeting the quality requirements of modern reeling and textile industries and for maintaining the competitiveness of the sericulture sector in national and international markets.

Objectives

1. To study the innovative techniques adopted in mulberry silkworm rearing.
2. To evaluate the impact of improved technologies on cocoon yield and quality.
3. To suggest strategies for sustainable and climate-resilient sericulture.

Materials and Methods

The present study has been conducted in Nalgonda, Suryapet and Warangal districts of Telangana state in India. Around 6 villages from these districts has been selected for the study. The present study was conducted based on both primary and secondary data used for the study. The survey method is used to collect the needed information about data, related to rearing practices. Both primary and secondary data were used for the study. The primary data was collected using a personal interview method and a prepared questionnaire schedule from the progressive farmers in Nalgonda, Suryapet and Warangal districts of Telangana state. Secondary data was collected from research publications and government of Telangana.

Mulberry Cultivation Practices

Installation of Rain Gun System

Rain guns are usually installed at a spacing of 18–24 meters between units to ensure uniform water distribution. The system was connected to a borewell or water source through PVC pipelines with adequate pressure of 2.5–4.0 kg/cm². A single 1.25-inch rain gun can cover approximately one acre in 2–3 hours. Irrigation was scheduled based on crop stage, soil moisture status, and seasonal requirements. Water discharge and irrigation duration were recorded. A typical rain gun covers 0.75 to 1 acre depending on pressure and nozzle size. 1 rain gun per acre is generally sufficient for effective irrigation.

Comparative Analysis of Rain Gun and Drip Irrigation in Mulberry Cultivation for Sericulture

Sl. No.	Parameter	Rain Gun Irrigation	Drip Irrigation
1	Irrigation Method	Sprinkler system that stimulates rainfall over entire mulberry field	Micro-irrigation system delivering water directly to root zone
2	Initial Installation Cost (per acre)	20,000	₹35,000 – ₹70,000
3	Water Use Efficiency (%)	50–65%	85–95%
4	Water Saving Compared to Flood Irrigation	30–40%	50–70%
5	Uniformity in Mulberry Fields	High uniform coverage of entire canopy	High root-zone uniformity but limited canopy wetting
6	Effect on Leaf Moisture	Increases leaf surface moisture temporarily	Maintains soil moisture without wetting leaves
7	Impact on Leaf Yield	Suitable for large-scale leaf production	Enhances nutrient-use efficiency and leaf quality
8	Fertigation Efficiency	Moderate precision	Very high precision (direct root feeding)
9	Weed Growth	Higher (entire soil surface wetted)	Lower (only root zone wetted)
10	Disease Incidence	Slightly higher risk of foliar diseases if humidity increases	Lower foliar disease risk
11	Energy Requirement	High (requires high pressure pump)	Moderate to low
12	Maintenance	Low; less clogging	Requires regular cleaning of emitters
13	Suitability for Large Mulberry Gardens	Highly suitable	Suitable but cost increases with area
14	Labour Requirement	Low	Moderate (monitoring lines and emitters)
15	Overall Suitability for Sericulture	Good for large farms with sufficient water	Best for water-scarce regions and precision nutrient management

Integrated Nutrient Management (INM)

Application of Farm Yard Manure (FYM) @ 10–20 tons/ha/year. Vermicompost @ 2–3 tons/ha/year. Biofertilizers such as Azotobacter and Phosphate Solubilizing Bacteria (PSB). Nutrients were applied in split doses after each leaf harvest to ensure sustained nutrient availability.

Bio-Fertilizer Azotobacter Nitrogen Fixer 8 kg/acre (split into 5 doses) Fixes atmospheric nitrogen; reduces Urea need by 25%. Azospirillum 8 kg/acre (split into 5 doses) Promotes root growth and nitrogen uptake. PS Phosphorus Solubilizer 8 kg/acre (split into 5 doses) Converts immobile soil phosphorus into a mobile form.

Results and Discussion

Yield and Growth Improvements

The technology used in rain guns significantly boosts growth

parameters:

Leaf Yield: Micro-sprinkler systems have recorded yields of approximately 13,123 kg/ha, which is roughly 23% higher than alternate furrow (flood) irrigation and nearly 11% higher than standard surface drip systems.

Growth Attributes: Taller plants and a higher number of branches and leaves per plant when compared to drip and subsurface systems.

Water Productivity: In rainfed or water-scarce regions like Nalgonda, these systems can improve leaf yield by 37% over traditional surface irrigation while saving significant amounts of water.

Moisture Retention: Atmospheric humidity in the range of 65–80% is ideal for mulberry. Rain guns maintain this range by misting the air, resulting in leaf moisture content of 70% or higher.

Protein Levels: Well-irrigated mulberry (especially using nitrogen-fixing misting) maintains a crude protein content of 23–24%, which is essential for the silkworm to produce high-quality silk fibre.

Succulence: By reducing the "transpiration stress" on the leaves during hot afternoons, rain guns keep the leaves succulent (soft and juicy) for a longer duration after harvest.

Annual Potential: Under optimal rain gun irrigation and recommended fertilizer doses, V1 can reach an annual yield of 60–65 Metric Tons (MT) per hectare, compared to only 50 MT under traditional methods.

Pest and Disease Suppression

Rain gun irrigation systems are emerging as an innovative technology in mulberry cultivation that contributes not only to efficient water management but also to the indirect control of pests and diseases. The high-pressure sprinkler mechanism distributes water uniformly across the mulberry canopy, creating an artificial rainfall effect. This process helps remove dust particles, insect eggs, and small pest populations from the leaf surface, thereby reducing the incidence of pests such as thrips, mites, and leaf rollers. Adequate moisture supplied through rain guns also reduces plant stress and promotes vigorous plant growth, which enhances the natural resistance of mulberry plants against pathogens. Additionally, rain gun systems can be utilized for the application of bio-pesticides, micronutrients, and organic formulations through fertigation, thereby improving integrated pest and disease management practices. Regular use of rain gun irrigation helps maintain a favorable microclimate within the mulberry field, minimizing the occurrence of certain fungal diseases associated with drought stress and poor plant vigor. Hence, rain gun technology plays a significant role in sustainable mulberry cultivation and supports improved leaf quality for successful silkworm rearing.

Tukra (Mealybug) Control: The high-pressure spray physically washes away mealybugs and their "honey-dew" secretions, which otherwise lead to sooty mold.

Thrips and Mites: These pests thrive in dry, dusty conditions. The regular "rain" created by the gun disrupts their breeding cycles and removes them from the leaf surface.

Cocoon Parameters:

Larval Weight: Larvae fed on high-moisture V1 leaves reached a 5th-instar weight of 32.02g per 10 larvae (compared to ~26g on lower-quality leaves).

Shell Ratio: The shell ratio the measure of how much silk is actually in the cocoon improved to 18.65–20%.

Overall Yield: Farmers using the V1 variety with modern irrigation have recorded yields of 70–75 kg of cocoons per 100 DFLs.

Table 1; Results of innovative techniques in mulberry silkworm rearing

Parameter	Before intervention practices	After intervention practices
No. of DFLs	250	250
Cocoon yield (kg/batch)	130	155
Gross income (Rs/batch)	73,900	85,800
Cost of cultivation (Rs)	13,757	11,557
Net income (Rs/batch)	60,150	74,143

Source; Data from progressive farmer, Suryapet.

1; Traditional practices 2; Innovative techniques

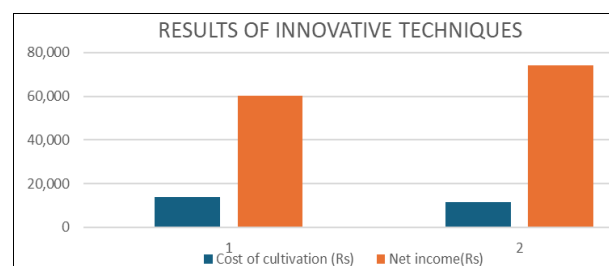


Fig 1: Indicates results of innovative techniques

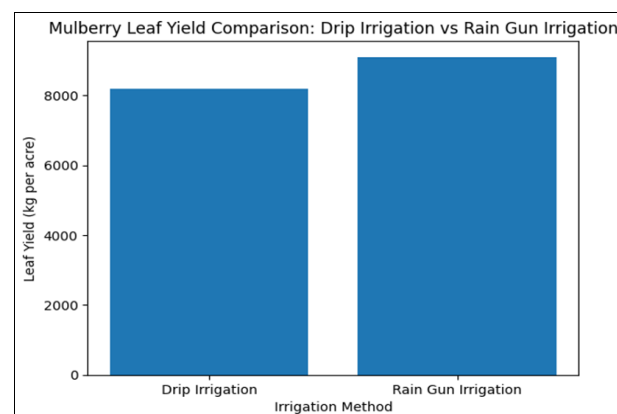


Fig 2: Comparison of Mulberry leaf yield using Drip irrigation and Rain gun irrigation

The comparison of mulberry leaf yield under drip irrigation and rain gun irrigation systems. The results indicate that rain gun irrigation recorded a higher leaf yield of 9,100 kg per acre compared to 8,200 kg per acre under drip irrigation. This represents an increase of approximately 900 kg per acre, or nearly 11% higher yield under rain gun irrigation. The improved performance under rain gun irrigation may be attributed to uniform water distribution, enhanced canopy humidity, and better vegetative growth of mulberry plants. In contrast, drip irrigation supplies water directly to the root zone, which conserves water efficiently but may not support uniform canopy development to the same extent. Overall, the findings suggest that rain gun irrigation can significantly enhance mulberry leaf productivity, thereby supporting improved silkworm rearing and cocoon yield.

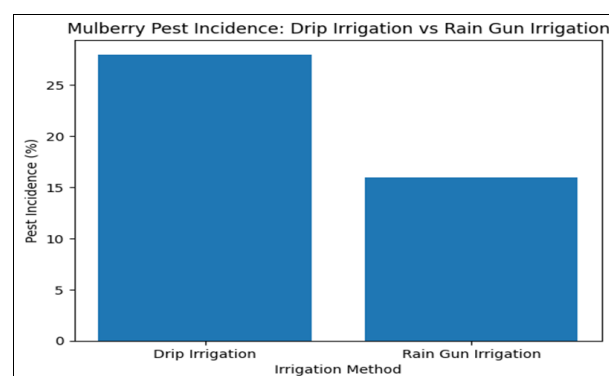


Fig 3: Pest incidence of Mulberry using Drip irrigation and Rain gun irrigation

Rain gun irrigation shows lower pest and disease incidence compared to drip irrigation because the water spray can wash off small insects and maintain canopy humidity, which may reduce pest buildup.

Integrated nutrient management

Biofertilizers like Azotobacter, Azospirillum, and Phosphobacteria significantly improve mulberry growth, leaf yield, and quality when combined with organic manures and reduced chemical fertilizers.

Growth Improvements

Poultry manure with Azotobacter boosted plant height by 22% (62.3 cm to 76.2 cm), shoots per plant to 7.8, and leaves per plant to 112. Micronutrients plus biofertilizers achieved 198 cm height, 14 shoots/plant, and 646 leaves/plant. These enhance rooting, survival, and photosynthesis for better vigor.

Cocoon Weight and Shell

Mulberry treated with biofertilizers like Azotobacter and VAM fungi increases fresh cocoon weight, shell weight, and shell ratio compared to chemical-only treatments. Studies show biofertilizer mixtures yield cocoon shell ratios up to 25%, with silk gland weights and filament lengths also improved.

Rearing Performance

Silkworms fed biofertilizer-enriched leaves exhibit better larval duration, pupation rates (up to 98%), and hatchability, reducing mortality versus inorganic fertilizer controls. VAM (*Glomus mosseae*) inoculation matches full phosphorus doses for cocoon yield and quality.

Economic Traits;

Reeling performance rises with FYM + phosphobacteria treatments, boosting filament length and weight for superior silk. Overall, biofertilizers support sustainable sericulture by maintaining cocoon quality while cutting chemical inputs.

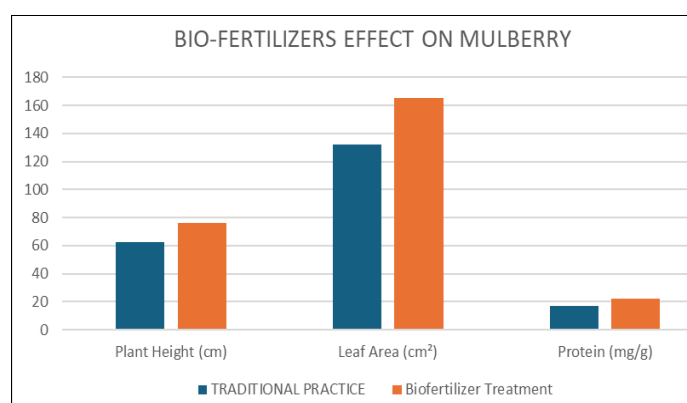


Fig 4: Effects of Bio-fertilizers on Mulberry

The effect of bio-fertilizers on mulberry growth and leaf quality parameters compared with traditional cultivation practices. The results indicate that the application of bio-fertilizers significantly improves plant growth and nutrient content in mulberry plants. The data presented, plant height under traditional practice was about 62 cm, whereas plants treated with bio-fertilizers reached approximately 76 cm, indicating better vegetative growth. Similarly, the leaf area increased from 132 cm² under traditional practice to around 165 cm² with bio-fertilizer treatment, suggesting enhanced leaf development and photosynthetic

capacity. The protein content of mulberry leaves, which is an important quality parameter for silkworm nutrition, also improved from about 17 mg/g in traditional practice to 21 mg/g under bio-fertilizer application.

These improvements may be attributed to the beneficial effects of bio-fertilizers such as nitrogen fixation, phosphorus solubilization, and improved soil microbial activity, which enhance nutrient availability and plant growth. Increased leaf area and protein content are particularly important in sericulture because they contribute to better silkworm growth, higher cocoon yield, and improved silk quality. Therefore, the use of bio-fertilizers can be considered an effective and sustainable approach for improving mulberry productivity and supporting eco-friendly sericulture practices.

Strategies For Sustainable and Climate-Resilient Sericulture

Climate change poses a significant challenge to sericulture, as both mulberry plants and silkworms (*Bombyx mori*) are highly sensitive to fluctuations in temperature, humidity, and rainfall. Transitioning to a sustainable, resilient model requires a two-pronged approach: strengthening the "food plant" (mulberry) and protecting the "producer" (the silkworm).

The key strategies to build a climate-resilient sericulture system

1. Climate-Smart Mulberry Cultivation

Mulberry leaves account for approximately 60% of the cost of cocoon production. Ensuring a steady supply of high-quality leaves during droughts or floods is critical.

Drought-Tolerant Varieties: Adopt cultivars specifically bred for water stress and high temperatures. In India, varieties like AR-12, G4, and Sahana are known for their resilience.

Precision Irrigation: Switch from flood irrigation to drip irrigation. This reduces water consumption by 40-50% and ensures moisture reaches the root zone directly.

Soil Health Management: Use organic mulching (with dried weeds or mulberry twigs) to retain soil moisture and suppress weed growth. Incorporating bio-fertilizers and green manure improves soil structure and water-holding capacity.

Tree-Type Plantations: In areas prone to fluctuating rainfall, growing mulberry as medium-sized trees rather than bushes helps the plant tap into deeper water tables and withstand surface-level heat.

2. Resilient Silkworm Rearing

Micro-Climate Control: Design rearing houses with high ceilings, thatched or tiled roofs (rather than asbestos/tin), and ridge ventilation to allow hot air to escape.

Evaporative Cooling: Use sand-and-brick cooling systems or humidifiers during dry summer months to maintain the ideal 70-80% humidity.

Robust Hybrids: Move toward Bivoltine hybrids that have been cross-bred for thermal tolerance. These hybrids can maintain silk quality even when temperatures occasionally drift outside the optimal range.

Disinfection and Hygiene: Climate change often leads to a surge in pests and pathogens. Implementing strict "Power Soaking" disinfection protocols for rearing equipment is essential to prevent crop loss.

3. Sustainable Resource Management

Sericulture can be a "zero-waste" industry if managed, which boosts economic resilience for farmers.

Waste Valorisation

Mulberry Shoots: Use leftover sticks for mushroom cultivation or as fuel.

Silkworm Litter (Frass): Convert this nitrogen-rich waste into high-quality vermicompost to be fed back into the mulberry garden.

Pupae: Use spent pupae (after reeling) as high-protein poultry or fish feed.

Solar Integration: Install solar panels on the roofs of rearing houses to power fans, lighting, and humidifiers, reducing reliance on the grid and lowering the carbon footprint.

4. Integrated Farming Systems (IFS)

To hedge against climate-related crop failure, farmers should avoid monoculture.

Intercropping: Grow short-duration crops like pulses, green gram, or vegetables between mulberry rows. This provides extra income and improves nitrogen fixation in the soil.

Border Planting: Plant tall trees like silver oak around the mulberry garden to act as windbreaks and reduce the "heat island" effect around the rearing house.

Conclusion

The integration of rain gun irrigation and integrated nutrient management (INM) practices plays a significant role in improving the sustainability and productivity of mulberry-based sericulture. Rain guns ensure uniform and efficient water distribution, maintain adequate soil moisture, and help reduce heat stress in mulberry fields, leading to improved leaf quality and higher biomass production. Proper irrigation also helps suppress certain pests and diseases by maintaining a balanced microclimate in the field. Integrated nutrient management further enhances mulberry growth by combining organic manures, chemical fertilizers, and biofertilizers to maintain soil fertility and nutrient balance. This approach improves soil structure, microbial activity, and nutrient availability, which ultimately results in healthier mulberry plants and better-quality leaves for silkworm feeding. The combined adoption of rain gun irrigation and INM practices not only increases mulberry leaf yield but also enhances silkworm growth, cocoon quality, and overall cocoon productivity. Moreover, these practices promote efficient resource utilization, reduce environmental impact, and support long-term soil health. The reduction in pest incidence under rain gun irrigation may be attributed to the washing effect of overhead water spray, which physically dislodges small insects such as thrips and mites from leaf surfaces. Additionally, uniform canopy moisture distribution may help in reducing stress conditions that favor pest multiplication. In contrast, drip irrigation supplies water only to the root zone, which conserves water efficiently but does not directly influence foliar pest populations. Therefore, integrating advanced irrigation technologies with balanced nutrient management is a promising strategy for achieving sustainable and profitable sericulture production under changing climatic conditions.

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