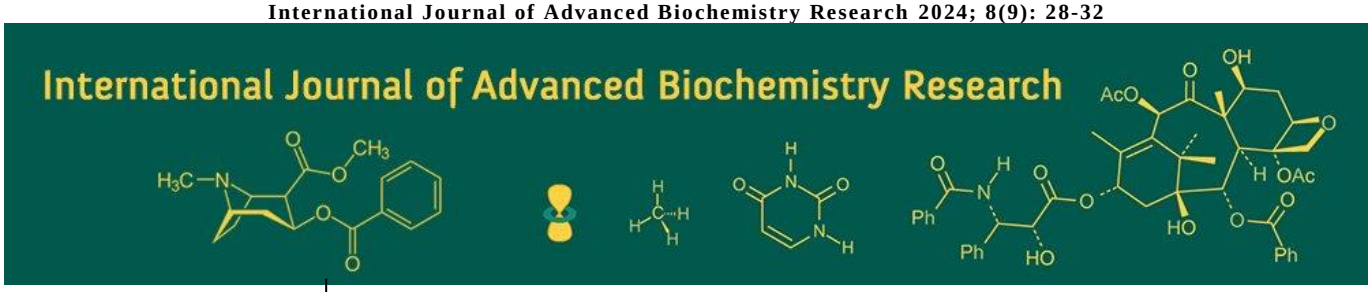

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A study to analyse pros and cons of different propagation methods in mulberry (*Morus* sp.)

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Abstract
Mulberry (*Morus spp.*) is a key plant in sericulture and has various uses in agroforestry, traditional medicine and food industries. Propagation of mulberry is essential to meet the increasing global demand, particularly in silk production and is achieved through both sexual and asexual methods each with distinct advantages and limitations. Sexual propagation involving seeds promotes genetic diversity which is crucial for breeding programs aimed at improving resistance to pests and environmental stresses. However, it introduces variability in plant traits which is undesirable in commercial sericulture. Asexual propagation methods such as cuttings, grafting, layering, mini clonal technology and tissue culture, provide uniform plants with consistent leaf yield and quality which are vital for silkworm rearing. While cutting propagation is simple and cost-effective, techniques like grafting and tissue culture offer better trait selection but require significant technical expertise and infrastructure. Mini clonal technology presents an advanced solution for large-scale propagation thereby combining speed with uniformity. This article comprehensively evaluates the pros and cons of each propagation method thus focusing on their suitability for different scales of mulberry cultivation and their impact on the silk industry. Recent advancements and research findings are integrated to highlight the future potential of mulberry propagation techniques.

Keywords: Cuttings, layering, grafting, mulberry propagation, mini clonal technology, seed propagation

1. Introduction
Mulberry (*Morus spp.*) is an essential plant with economic and cultural significance, particularly in sericulture where its leaves are the primary food for silkworms (*Bombyx mori* L.). Mulberry cultivation has long been integral to the silk industry especially in countries like China, India, Japan and Thailand, where silk production plays a major role in rural economies. Beyond sericulture, mulberry has gained prominence in agroforestry, soil conservation, traditional medicine and even the food industry thus contributing to its global demand (Miah *et al.*, 2022) [19]. As a result, establishing efficient propagation methods for mulberry has become critical to ensuring consistent and sustainable production (Bharathi *et al.*, 2024) [5-14].

Mulberry can be propagated through sexual and asexual methods each with its advantages and challenges. Sexual propagation involving seeds thus offers the benefit of genetic diversity which is vital for breeding programs aiming to enhance resistance to diseases and environmental stressors (Bharathi *et al.*, 2024) [5-14]. However, seed propagation introduces variability in plant characteristics such as growth rates and leaf quality which can be a disadvantage in sericulture where uniformity is key (Kumar *et al.*, 2023) [17]. Additionally, plants propagated from seeds often experience a longer juvenile phase thereby delaying economic returns (Verma *et al.*, 2021) [26].

In contrast, asexual propagation methods such as cuttings, grafting, layering, mini clonal technology and tissue culture produce genetically identical plants thus ensuring uniformity in growth and leaf yield (Bharathi *et al.*, 2024) [5-14]. This uniformity is particularly valuable in sericulture, where consistent quality and quantity of mulberry leaves directly impact silkworm productivity and silk quality (Liang *et al.*, 2021) [18]. Cuttings, the most common method of vegetative propagation are simple and inexpensive but success rates can be variable depending on environmental conditions and plant varieties.

(Nakamura *et al.,* 2023) [22, 23]. Grafting and budding while allowing the combination of desirable traits, require technical skill and can be labour-intensive thus making them less suitable for large-scale operations (Nair *et al*., 2022) [20, 21].

Emerging techniques like mini clonal technology and tissue culture have transformed large-scale propagation efforts (Bharathi *et al*., 2024) [5-14]. Mini clonal technology involves the rapid production of small clonal plants through specialized techniques that optimize growth conditions and use rooting hormones (Bharathi *et al*., 2024) [5-14]. It allows for faster, more efficient propagation of high-quality and uniform plants although it requires significant investment in infrastructure (Agarwal *et al*., 2022) [1, 2]. Similarly, tissue culture enables the production of disease-free, uniform plants in controlled environments, making it ideal for commercial operations (Bharathi *et al*., 2024) [5-14]. However, the costs associated with tissue culture thereby including specialized equipment and expertise often restrict its use to large enterprises (Chen *et al*., 2022) [27, 28].

This article explores the various propagation methods used in mulberry cultivation thereby analysing their pros and cons. By evaluating the strengths and limitations of each propagation technique, we aim to provide insights that can assist farmers, researchers and industry professionals in selecting the most appropriate methods for their specific needs and circumstances (Bharathi *et al.,* 2024) [5-14]. Emphasis will be placed on both traditional and modern propagation techniques, with a focus on recent advancements and their potential applications in enhancing mulberry production for sericulture and other industries (Zhao *et al.,* 2022) [27-29].

2. Sexual Propagation through Seeds

Pros

1. **Genetic Diversity:** Sexual propagation offers natural genetic variation which can increase resistance to pests and diseases (Miah *et al.,* 2022) [19]. It promotes the development of new varieties through cross-pollination and hybridization (Zhao *et al.,* 2022) [27-29].
2. **Cost-effective:** Seeds are generally cheaper than other planting materials like cuttings or tissue-cultured plants (Bharathi *et al.,* 2024) [5-14]. Propagation by seed requires minimal infrastructure thereby making it a cost-effective option for farmers with limited resources (Kumar *et al.,* 2023) [17].
3. **Longer Lifespan:** Seed-grown plants often exhibit a longer lifespan and are more robust as they develop from a complete embryo thus forming a tap root system that offers better anchorage and resistance to drought (Verma *et al.,* 2021) [26].

Cons

1. **Variability in Offspring:** The major disadvantages of sexual propagation is the lack of uniformity in the offspring. Variability in plant characteristics can result in unpredictable leaf yields and quality thus making it less suitable for commercial silk production where consistency is key (Liang *et al.,* 2021) [18].
2. **Extended Juvenile Period:** Seed-propagated plants may take several years to reach maturity and begin producing leaves suitable for feeding silkworms. This delays the economic returns for farmers (Singh & Rao, 2020) [25].
3. **Seed Dormancy Issues:** Some mulberry seeds exhibit dormancy, requiring special treatments like stratification to germinate (Bharathi *et al.,* 2024) [5-14]. This adds to the complexity and time required for seed-based propagation (Zhao *et al.,* 2022) [27-29].

3. Asexual Propagation Methods

3.1 Propagation by Cuttings

Propagation by cuttings involves taking sections of stems, roots or leaves from a parent plant and inducing them to develop roots and shoots.

Types of Cuttings

1. **Hardwood Cuttings:** These are taken from mature, dormant woody stems during the winter season (Park *et al.,* 2023) [24].
2. **Softwood Cuttings:** Taken from the tender, actively growing parts of the plant during the spring and summer (Bharathi *et al.,* 2024) [5-14].

Pros

1. **Uniformity:** Cuttings produce plants genetically identical to the parent plant thereby ensuring consistency in leaf quality, yield and growth characteristics, which is critical in commercial mulberry cultivation for sericulture (Agarwal *et al.,* 2022) [1, 2].
2. **Faster Establishment:** Plants propagated from cuttings establish and begin producing leaves faster than those grown from seeds thus reducing the time needed to start harvesting mulberry leaves (Nakamura *et al.,* 2023) (Nakamura *et al.,* 2023) [22, 23].
3. **Ease of Practice:** The technique of taking cuttings is simple and requires no sophisticated equipment thereby making it accessible for small-scale farmers (Bharathi *et al.,* 2024) [5-14].

Cons

1. **Limited Rooting Potential:** Not all mulberry varieties root easily from cuttings. Some may require rooting hormones or other treatments to encourage root development (Chen *et al.,* 2022) [27, 28].
2. **Disease Transmission:** A major drawback of clonal propagation is the potential for disease transmission from parent plants to offspring. Pathogens, particularly viruses can be inadvertently propagated thus leading to widespread plant health issues (Kumar *et al.,* 2021) [16].
3. **Water Dependency:** Cuttings require consistent moisture to successfully root thereby making this method less suitable for regions with limited water availability. Drought or improper irrigation can result in high failure rates (Singh & Rao, 2020) [25].

3.2 Grafting and Budding

Grafting and budding involve joining two plant parts-typically the rootstock (base) and scion (top part)-to grow as a single plant. The purpose of grafting is to combine desirable characteristics of both plants.

Pros

1. **Combining Traits:** Grafting allows for the combination of traits such as disease resistance in the rootstock with high yield and quality in the scion. This can enhance the overall performance of the plant (Nair *et al.,* 2022) [20, 21].

2. **Longevity:** Grafted plants tend to be more robust and can have a longer productive lifespan compared to plants propagated through cuttings or seeds.
3. **Disease Resistance:** By selecting disease-resistant rootstock, grafted plants can be more resistant to soil-borne pathogens thus providing an advantage in disease-prone areas (Das *et al.*, 2021) [4, 16].

Cons

1. **Technical Skill Required:** Grafting requires a higher level of expertise compared to other propagation methods. The success of grafting depends on the precision with which the scion and rootstock are joined and the care taken during the healing process (Park *et al.*, 2023) [24].
2. **Labour Intensive:** The process is labour-intensive and time-consuming thereby making it less viable for large-scale commercial operations where rapid propagation is necessary (Bharathi *et al.*, 2024) [5-14].
3. **Compatibility Issues:** Grafting is not always successful, especially when there is incompatibility between the scion and rootstock thus leading to graft rejection or failure (Chen *et al.*, 2022) [27, 28].

3.3 Layering

Layering is a method of vegetative propagation where a portion of the stem is induced to form roots while still attached to the parent plant. Once rooted, the new plant is separated from the parent and planted independently (Bharathi *et al.*, 2024) [5-14].

Types of Layering

1. **Air Layering:** Involves wrapping a section of stem in a moist medium (e.g., sphagnum moss) to encourage root formation (Agarwal *et al.*, 2022) [1, 2].
2. **Ground Layering:** Involves stretching a stem to the ground and covering part of it with soil until it roots (Bharathi *et al.*, 2024) [5-14].

Pros

1. **High Success Rate:** Since the new plant remains attached to the parent until it is well-established, the success rate is generally higher than with cuttings, particularly for difficult-to-root varieties (Singh & Rao, 2020) [25].
2. **Minimal Equipment Needed:** Layering can be done with little to no specialized equipment thereby making it a low-cost propagation method.
3. **Strong Root System:** Layered plants often develop strong, well-formed root systems thus leading to healthier and more vigorous plants after separation (Kumar *et al.*, 2023) [17].

Cons

1. **Limited Production Capacity:** Layering is a slow process and does not allow for large-scale propagation. Each new plant takes time to develop thus making it less suitable for commercial propagation where mass production is needed (Liang *et al.*, 2021) [18].
2. **Space Requirements:** Layering requires the plant to remain in place for an extended period which can limit the available space for other agricultural activities (Das *et al.*, 2021) [4, 16].

3.4 Mini Clonal Technology

Mini clonal technology is an advanced vegetative propagation technique involving the use of small shoots or "mini cuttings". The shoots are treated with rooting hormones and placed in a controlled environment to promote root development (Bharathi *et al.*, 2024) [5-14].

Pros

1. **High Propagation Rate:** Mini clonal technology allows for rapid and large-scale propagation of mulberry plants thereby making it highly efficient for commercial use (Liang *et al.*, 2021) [18].
2. **Uniformity:** Like other asexual methods, mini clonal technology produces genetically identical plants thus ensuring uniform growth and leaf yield (Chen *et al.*, 2022) [27, 28].
3. **Reduced Space Requirement:** This method can be implemented in small, controlled environments thereby reducing the land required for propagation (Das *et al.*, 2021) [4, 16].
4. **High Survival Rate:** The controlled environment and use of rooting hormones lead to a higher survival rate than traditional cutting methods (Nakamura *et al.*, 2023) [22, 23].

Cons

1. **High Initial Investment:** Mini clonal technology requires significant investment in infrastructure such as mist chambers, humidity control systems and rooting hormone treatments thus making it less accessible for small-scale farmers (Nair *et al.*, 2022) [20, 21].
2. **Technical Expertise:** Successful application requires training and technical skills, which can limit adoption among farmers lacking such resources (Kumar *et al.*, 2023) [17].

3.5 Tissue Culture (Micropropagation)

Tissue culture involves cultivating plant tissues in a controlled environment to produce clones of the parent plant. It is used commonly for commercial-scale propagation.

Pros

1. **Rapid Propagation:** Tissue culture enables the production of large numbers of uniform plants quickly thus making it ideal for commercial operations (Chen *et al.*, 2022) [27, 28].
2. **Disease-Free Plants:** Plants propagated through tissue culture are generally free from pathogens, as the process is conducted under sterile conditions (Zhao *et al.*, 2022) [27-29].
3. **Uniformity in Growth:** Plants propagated through tissue culture are mostly uniform when compare to plants propagated by seedlings.

4. Conclusion

The propagation of mulberry (*Morus spp.*) plays a critical role in the sustainability and efficiency of the sericulture industry and other sectors utilizing this versatile plant. Understanding the strengths and limitations of various propagation methods is key to optimizing mulberry

production. Sexual propagation through seeds while offering genetic diversity, is less favoured in commercial settings due to the variability in plant characteristics and the delayed maturation period. This method is more suitable for breeding programs aimed at developing new varieties with improved traits. In contrast, asexual propagation methods-such as cuttings, grafting, layering, mini clonal technology and tissue culture-offer uniformity in plant traits, essential for ensuring consistent leaf yield and quality. These methods are more applicable to large-scale commercial sericulture where uniformity directly impacts the health of silkworms and the quality of silk produced. Cuttings are widely used due to their simplicity and low cost though they may not always provide the best rooting success. Grafting and layering offer advantages in combining desirable traits but require technical expertise. Advanced methods like mini clonal technology and tissue culture represent the future of mulberry propagation thus offering rapid, disease-free and uniform plant production with higher costs and technical demands. Ultimately, the choice of propagation method should align with the specific needs of the producer whether focused on research, breeding or commercial-scale cultivation. Emphasizing recent advancements and tailored techniques will enhance the productivity and sustainability of mulberry plantations across diverse agricultural landscapes.

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