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Impact of reeling effluent irrigation on soil properties in mulberry garden: An overview

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Abstract
Sericulture, primarily based on the cultivation of mulberry and rearing of the silkworm *Bombyx mori*, plays a vital role in rural livelihoods and sustainable agriculture. With increasing pressure on freshwater resources, the use of alternative irrigation sources such as reeling effluent-wastewater generated during silk production is gaining importance. Rich in essential nutrients like nitrogen, phosphorus, potassium, calcium and magnesium, reeling effluent has shown potential to enhance mulberry growth, leaf yield, and soil fertility when used judiciously. This review explores the chemical composition of reeling effluent, its application in mulberry cultivation and its effects on soil physico-chemical and biological properties. Research findings indicate that effluent irrigation improves organic carbon levels, microbial activity and nutrient availability in soil. However, untreated discharge of reeling effluent can cause environmental issues such as eutrophication and contamination of soil and water bodies. Sustainable management strategies like bioremediation and controlled application are necessary to harness the benefits while minimizing ecological risks. The study supports reeling effluent irrigation as a resource-efficient and environmentally sound practice in sericulture.

Keywords: Sericulture, mulberry, *Bombyx mori*, reeling effluent, soil fertility, sustainable agriculture

Introduction
Silk fibre is referred as "The Queen of Textiles" because of its unique properties *viz.*, natural sheen, innate affinity for dyes, rich array of colours, high absorbency, light weight feel, remarkable resilience and excellent drape quality characteristics. Various silkworm species yield distinct types of silk, the highest quality often attributed to mulberry silk. This premium silk is produced by the mulberry silkworm. The name mulberry originates from the plant which serves as its primary host for food source. Water is one of the most important and limited natural resources with 70 per cent of the world fresh water used for agriculture. Wastewater generated from different sources can be used as alternate source irrigation, which helps to partially alleviate the scarcity of ground water. Water has numerous application and also crucial to meet the increased need of agricultural productivity. Water conservation, nutrient recycling in wastewater, a reduction in the direct use of organic fertilizers and a reduction in the polluting of water bodies are all aided by the alternative agricultural method known as wastewater irrigation (Datta., 2000) [7]. Recently wastewater is being applied to agricultural lands to substitute nutritional requirement of crops. In certain areas due to scarcity of water farmers are using the effluent as source of irrigation water as well as source of plant nutrients. This is supposed to solve the problem of disposal as well as source of irrigation and nutrients for crop production.

Using different types of wastewater such as sewage water, distillery spent wash, silk reeling effluent and industrial waste discharge for irrigation beneficial for the growth and development of mulberry plants. Particularly, using reeling wastewater in mulberry cultivation has shown positive effects in mulberry growth and development (Kalpana *et al.*, 2018) [10]. During the production of silk fibre, a considerable quantity of wastewater is generated from silk reeling units. It was estimated that 1.000-3.000 m³ of reeling effluent is being generated per day for every 12-20 tonnes of silk fabric production (Akter, 1998) [1]. Reeling effluent consist of major nutrients like nitrogen (13.57 mg/l), phosphorus (1.15 mg/l), potassium (22.68 mg/l) and minor nutrients like calcium, magnesium and chloride (109.6 mg/l,37.44 mg/l and 28.4 mg/l, respectively).

So, utilization of wastewater for the cultivation of mulberry is effective and ecofriendly.

Irrigation in Mulberry Cultivation

Irrigation is a vital component in mulberry (*Morus* spp.) cultivation, as it directly influences leaf yield and quality, which are essential for successful silkworm rearing. Mulberry requires a consistent and adequate water supply due to its shallow root system and high biomass production. The need for irrigation varies with soil type, climate, mulberry variety, and method of cultivation.

1. Importance of Irrigation

- Water stress adversely affects leaf yield, protein content, moisture level, and palatability of leaves, leading to poor silkworm growth and cocoon quality.
- Regular irrigation ensures sustained leaf production throughout the year, especially in tropical and semi-arid regions.

2. Irrigation Methods

The major irrigation methods used in mulberry cultivation are:

a. Surface Irrigation (Furrow and Basin)

- Widely used in India due to low cost and simplicity.
- Furrow method is ideal for row planting and provides uniform distribution of water.

b. Drip Irrigation

- Efficient in terms of water use and yield.
- Reduces weed growth, labor cost, and disease incidence.
- A study reported a 30-40% increase in water use efficiency and 25-30% increase in leaf yield through drip irrigation (Ramesha., *et al.*, 2011) [18].

c. Sprinkler Irrigation

- Suitable for undulating terrain.
- Helps maintain optimal humidity, especially beneficial in dry regions.

3. Irrigation Scheduling

- Frequency: Mulberry requires irrigation every 7-10 days during summer and 15-20 days in winter, depending on soil moisture.
- Water Requirement: Annual water requirement ranges between 1200-1500 mm, varying with the agro-climatic zone (Datta, 2000) [7].
- Mulberry grown under irrigated conditions can produce 40-60 tons/ha/year of leaf yield as compared to 8-12 tons under rainfed conditions.

4. Water Management Practices

- Soil moisture conservation through mulching and organic matter improves water retention.
- Use of moisture sensors or tensiometers for precise irrigation scheduling is encouraged.
- Alternate furrow irrigation and deficit irrigation strategies are also gaining importance for water conservation

Chemical Composition of reeling effluent

India is the second largest raw silk-producing country with an annual production of 15818 MT in 2021-2022. During the production of silk fibre, a considerable quantity of wastewater is generated from silk reeling units. It was estimated that 1.000-3.000 m³ of reeling effluent is being generated per day for every 12-20 tonnes of silk fabric production (Akter, 1998) [1].

Reeling effluent is primarily composed of water, proteins (mainly fibroin and sericin), amino acids, salts, and trace metals (Choudhury & Sahoo, 2021) [5]. Fibroin is the main structural protein of silk fibers, and sericin is the protein that holds the fibroin strands together. The effluent contains a high concentration of organic matter, including sugars, lipids, and amino acids, which are the byproducts of the reeling process (Siddique *et al.*, 2020) [20]. The composition of the effluent can vary depending on the sericulture method and reeling process used. In addition to proteins, effluent may contain residual chemicals such as detergents, oils, or dyes, which complicate its treatment and reuse (Singh *et al.*, 2022) [21].

And also reeling effluent consist of major nutrients like nitrogen (13.57 mg/l), phosphorus (1.15 mg/l), potassium (22.68 mg/l) and minor nutrients like calcium, magnesium and chloride (109.6 mg/l,37.44 mg/l and 28.4 mg/l, respectively).So, utilization of wastewater for the cultivation of mulberry is effective and ecofriendly.

Wastewater treatment

Due to its high organic content, reeling effluent has been studied for its potential in wastewater treatment. The effluent can be utilized as a co-substrate in bioreactors for anaerobic digestion, promoting the production of biogas (Priyanga *et al.*, 2019) [19]. The microorganisms involved in anaerobic digestion can break down the organic matter in the effluent, turning it into methane and other usable by-products. Furthermore, reeling effluent has been tested in the treatment of industrial wastewater, where it can help remove pollutants by acting as a nutrient source for bioremediation. In this way, the effluent can play a dual role in both treating wastewater and reducing the environmental load of sericulture operations.

Effect of reeling effluent irrigation on soil physical and chemical property

Reeling effluent, when applied to agricultural fields, can influence soil physical and chemical properties**.** Physically, it may affect soil texture, porosity, bulk density and water holding capacity by contributing organic matter and altering soil structure. Chemically, the effluent introduces nutrients such as nitrogen (N), phosphorus (P) and potassium (K)**,** as well as micronutrients like magnesium, calcium, and chloride**,** which can enhance soil fertility.

However, the long-term impact depends on the composition, pH, electrical conductivity (EC) and organic load of the effluent. Improper or excessive use may lead to soil salinization, altered pH and microbial imbalances**.** Hence, understanding the influence of reeling effluent irrigation on soil health is crucial for its sustainable use in sericulture-based farming systems.

Soil pH and chemical interactions

The pH of soil irrigated with wastewater is influenced by the chemical composition of the water and the microbial activity in the rhizosphere. Wastewater rich in organic acids may initially be acidic but can lead to a rise in soil pH due to microbial degradation of these acids into neutral end products (Ashrith *et al.*, 2024) [15]. On the other hand, neutral sewage water may decrease soil pH because soil microbes produce carbon dioxide (CO_2), which forms carbonic acid in the soil, and other organic acids during the decomposition of organic matter (Angin *et al.*, 2005) [2]. Over time, such processes reduce soil pH. Additionally, long-term wastewater irrigation increases soluble salt content, which can alter cation exchange processes and further affect soil pH. Studies by Narwal *et al.* (1993) [14] and Singh and Verloo (1996) [24] confirm these effects, showing decreased soil pH alongside increased EC and organic carbon levels.

Electrical conductivity and nutrient enrichment

Wastewater typically contains dissolved salts, minerals, and nutrients like nitrogen, phosphorus, and potassium, which contribute to increased electrical conductivity (EC) and soil fertility. High EC results from the accumulation of soluble ions such as Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, and SO_4^{2-}, which are commonly present in wastewater. Das *et al.* (2003) [6] demonstrated significant increases in soil EC and major nutrients in mulberry fields irrigated with sewage water. Similarly, Singh *et al.* (2013) [22] found increased nutrient availability and soil EC under paper mill effluent irrigation. These changes enhance nutrient retention and uptake by plants, particularly in nutrient-deficient soils. Kalpana *et al.* (2018) [10] also showed that wastewater from various sources contributed meaningful amounts of N, P, and K, thus acting as a liquid biofertilizer. This enrichment is largely due to direct addition of nutrients and the stimulation of microbial mineralization of organic matter.

2.3. Microbial activity and soil biology

Wastewater irrigation impacts microbial populations by introducing organic substrates and nutrients that stimulate microbial proliferation. Raw sewage, in particular, supplies ample organic matter that supports microbial growth, resulting in increased populations of beneficial microbes like *Azotobacter*, fungi, and actinomycetes (Ramanathan *et al.*, 1977) [17]. These microbes play key roles in nitrogen fixation, organic matter decomposition, and nutrient cycling. Tripathi *et al.* (2014) [26] reported that effluent irrigation enhanced both structural and functional diversity of microbial communities. However, continuous use of untreated sewage may also suppress certain heterotrophic microbial populations due to accumulation of toxic compounds or anaerobic conditions, impairing organic matter decomposition (Das *et al.*, 2003) [6]. Furthermore, changes in soil pH and EC influence the ionic environment of the rhizosphere, indirectly affecting microbial activity and soil respiration rates (Sushil and Garhwal, 2018) [25].

Physical soil properties

Long-term irrigation with wastewater influences soil physical characteristics by altering its structure and porosity. Gurjar *et al.* (2017) [8] observed that wastewater application increased bulk density, particle density, porosity, and water-holding capacity (WHC), likely due to higher organic matter inputs and microbial activity that improve aggregate stability. Increased microbial biomass and exudate act as binding agents that enhanced soil structure. Wastewater also increases soluble salt concentration, affecting soil permeability and infiltration. Muamar Al-Jaboobi *et al.* (2014) [13] found higher EC and slightly reduced pH in wastewater-treated soils, indicating changes in soil ionic composition that can influence water movement and root aeration. Singh *et al.* (2012) [23] further showed that wastewater, when applied with balanced fertilizers, improves soil fertility and boosts crop productivity due to enhanced nutrient cycling and better moisture retention.

Environmental impact of reeling effluent

The disposal of reeling effluent without proper treatment can cause significant environmental harm. The high organic load in the effluent can lead to oxygen depletion in water bodies, potentially causing eutrophication and adversely affecting aquatic life (Narwal *et al.*, 1993) [14]. Furthermore, the residual chemicals used during the reeling process can contribute to soil and water contamination, thus posing a threat to ecosystems. In recent years, several studies have highlighted the environmental benefits of reusing reeling effluent through processes such as bioremediation or conversion into value-added products. The sustainable management of this effluent is essential for mitigating its environmental impact while ensuring that sericulture continues to thrive as a livelihood for millions.

Disclaimer (Artificial intelligence)

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

Competing Interests

Authors have declared that no competing interests exist.

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