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Harnessing mulberry trees for carbon sequestration: A review of strategies to enhance air quality

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Abstract
Mulberry trees (genus *Morus*) hold great promise for reducing atmospheric CO_2 levels and improving air quality due to their remarkable ability to sequester carbon. This review article examines various strategies used to maximize the carbon sequestration potential of mulberry trees, thereby contributing to enhanced air quality. The main factors influencing mulberry tree-mediated carbon sequestration are discussed, such as photosynthetic efficiency, biomass accumulation, and pollutant absorption capacities. Furthermore, the review investigates the role of mulberry trees in phytoremediation efforts, focusing on contaminated soil sites near industrial zones. Additionally, cultivation practices such as mulching, irrigation methods, and tillage techniques are evaluated for their effectiveness in optimizing carbon sequestration in mulberry plantations. The review emphasizes the importance of temperate climate conditions, such as those found in areas like Kashmir, for promoting long-term carbon storage in mulberry trees. The findings of this review provide valuable guidance for policymakers, environmentalists, and agricultural practitioners looking to use mulberry trees as powerful allies in the global fight against climate change and air pollution.

Keywords: Mulberry trees, carbon sequestration, phytoremediation, air pollutants, soil remediation, sustainable practices

Introduction

Plants act as nature's thermostat, absorbing carbon dioxide from the atmosphere and releasing oxygen to help mitigate global warming (Rohela *et al.*, 2020) [18]. This oxygen production purifies the air and keeps animals and other organisms alive. Bowman *et al.* (2011) [2] claim that prior to human expansion, the Earth was in a state of minimal disruption, with abundant biodiversity. However, since the nineteenth century, rapid urbanization and population growth have resulted in the release of significant amounts of non-biodegradable waste, chemical pollutants, and harmful gases into the environment via domestic, vehicular, and industrial sources (Minghua *et al.*, 2009) [13]. These anthropogenic activities, combined with industrialization and fossil fuel combustion, have resulted in a significant increase in atmospheric CO_2 levels, surpassing the 400-ppm threshold, as highlighted by Yadav *et al.* (2020) [25]. This surge in carbon dioxide concentration is a primary driver of global warming, contributing to the escalating global temperatures. Lavania and Lavania (2009) [27] report a concerning trend of global warming accelerating at a rate of 0.2 °C per decade. This trajectory predicts an average global temperature increase of 3 °C by 2100. This phenomenon is believed to be linked to rising levels of atmospheric CO_2.

Several researchers, including Abdullahi *et al.* (2018) [1] and Toochi (2018) [23], advocate for capturing atmospheric CO_2 and storing it in soils as a major strategy for reducing greenhouse gas emissions. Susarla *et al.* (2002) [21] supported phytoremediation, a plant-based environmental clean-up technology, as a promising green solution. Yadav *et al.* (2020) [25] highlight the ability of agroforestry systems, particularly those that include trees and shrubs, to capture CO_2 and convert it into biomass via photosynthesis. The same study found that this process improves long-term soil carbon storage. The enhanced carbon sequestration capacity of these systems is attributed to efficient resource utilization by diverse plant communities, as explained by Steinbeiss *et al.* (2008) [20]. Koul and Panwar (2008) [28] acknowledged the terrestrial biosphere's ability to absorb and retain atmospheric CO_2, highlighting it as a viable and cost-effective approach to mitigating carbon emissions. Focusing on India, Yadav *et al.* (2020) [25] investigate the carbon sequestration potential of mulberry, a C3 plant widely cultivated for its leaves and known for its high CO_2 fixation rate. This review looks at mulberry's ability to store carbon in its aboveground biomass and enrich soil carbon stocks.

Multifarious role of mulberry

According to Hashemi and Tabibian (2018) [8], certain tree species excel at soil remediation, while Shi *et al.* (2005) [19] identify others capable of purifying air and water. Furthermore, Shi *et al.* (2005) [19] highlight specific tree types for ecorestoration and soil conservation. Del *et al.* (2013) [4] discuss trees contribution to economic growth and health benefits. While some tree species excel in certain areas, none have all of these desirable characteristics. Interestingly, Rohela *et al.* (2020) [18] argue that mulberry (*Morus* spp.) is a unique exception, possessing all of these characteristics, making it a particularly valuable plant species.

Fig 1: Multifarious role of Mulberry as a Plant

Mulberry in promoting environmental sustainability

Several studies have demonstrated the suitability of mulberry plants for environmental remediation and conservation. Vijayan *et al.* (2000) [24] emphasize the perennial, woody nature of these plants, as well as their deep and spreading root systems, which make them ideal for various soil pollutants. Peng *et al.* (2012) [15], Jothimani *et al.* (2013) [10], and Zhou *et al.* (2015) [26] conducted research that specifically demonstrated their effectiveness in dealing with heavy metals such as lead, cadmium, and copper. Du *et al.* (2011) [5] state that cultivating mulberry trees promotes water and soil conservation. Furthermore, Lu *et al.* (2004) [12] highlights their high rate of carbon sequestration, which makes them useful for reducing air pollution.

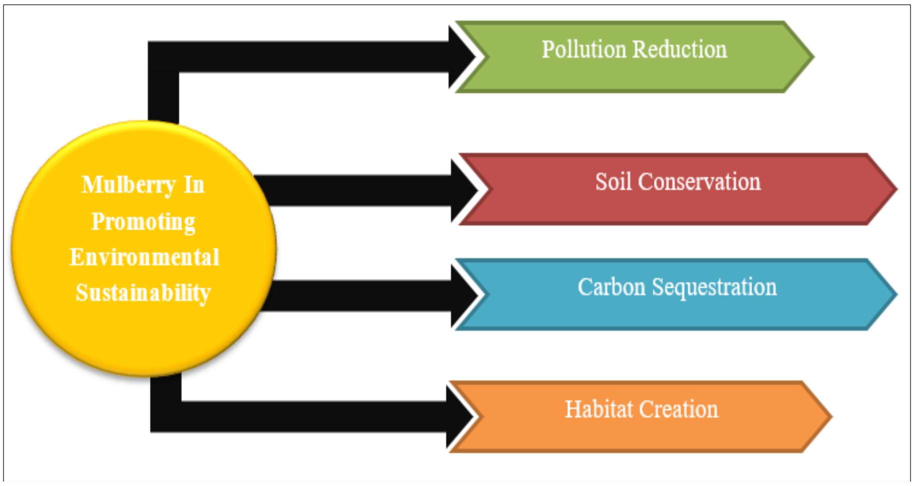

Fig 2: Mulberry in promoting Environmental Sustainability

Role of Mulberry in Carbon Sequestration:

Carbon sequestration, in other words, is the long-term storage of carbon in environments such as oceans, soil, plants (particularly forests), and other geological formations. Photosynthesis is the process by which plants absorb carbon dioxide from the atmosphere. Some of this carbon is then consumed by animals which is returned to the soil through dead plant matter, animal waste, and decomposition, as explained by Rathore and Srinivasulu (2018) [17].

According to research, mulberry plants show promise for improving air quality. Their rapid growth, high biomass, and robust photosynthetic abilities all contribute to this advantage (Jiang *et al.*, 2017) [9]. Mulberry leaves are especially beneficial at absorbing air pollutants such as carbon dioxide, carbon monoxide, and even harmful compounds like hydrogen fluoride and sulfur dioxide (Lu *et al*., 2004; Ghosh *et al.*, 2017) [12, 7]. The roots also play a vital part. With a large diameter near the stem that tapers down to a fibrous network of fine roots and root hairs, they are capable of absorbing not only carbon pollutants but also heavy metals from the soil (Olson and Fletcher, 1999; Bunger and Thomson, 1938; Farrar, 1995) [14, 3, 6]. According to Rohela *et al.* (2020) [18], mulberry trees are valuable tools for carbon sequestration and heavy metal remediation due to their unique combination of aerial and root-based absorption capabilities.

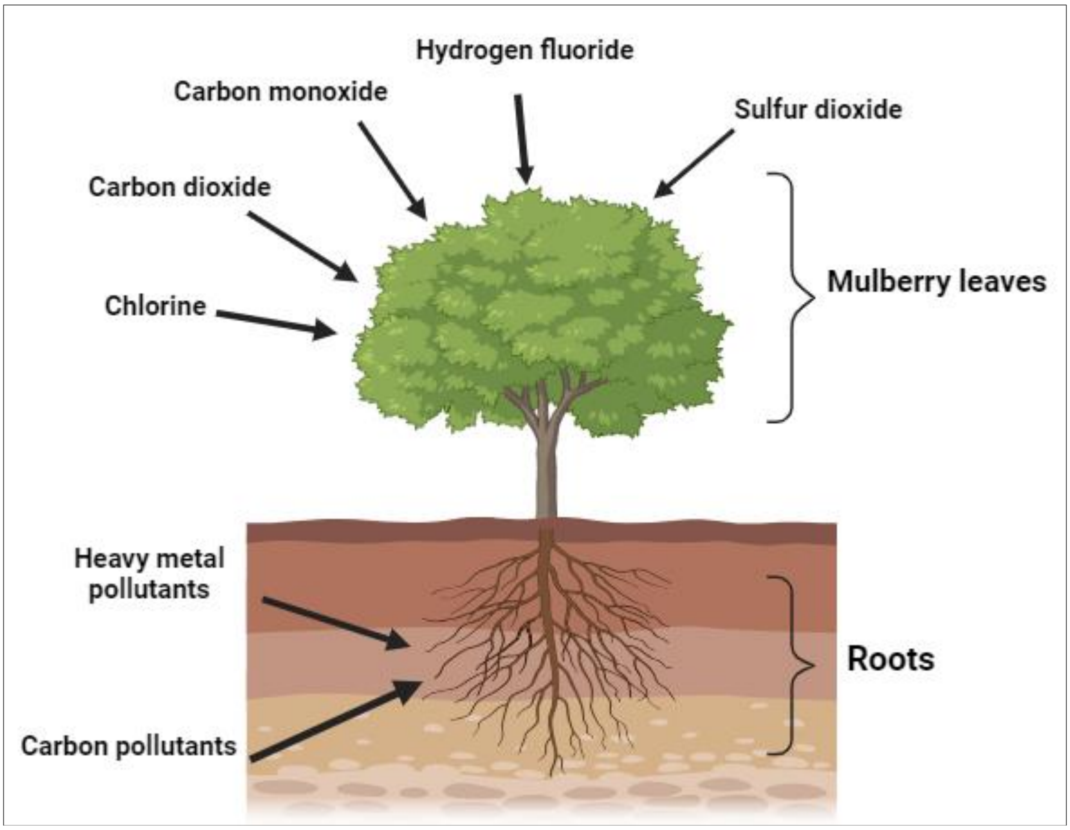

Fig 3: Pollutants absorbed by Mulberry leaves and its roots

According to studies, mulberry trees benefit the environment in a variety of ways. Ghosh *et al.* (2017) [7] estimated that a single mulberry tree can absorb 4162 kg of CO_2 and emit 3064 kg of oxygen per year. On a larger scale, Tan *et al*. (2010) [22] proposed that one hectare of mulberry trees could absorb an impressive 1 ton of CO_2 per day and release 0.73 tons of oxygen, which is enough to meet the breathing needs of 1000 people. However, Qin *et al.* (2010) [16] provided a slightly lower, but still significant estimate, claiming that a hectare of mulberry trees could absorb 49.29 tons of CO_2 and release 35.85 tons of oxygen per year. Mulberry trees are ideal candidates because of their remarkable phytoremediation abilities, particularly in cleaning up contaminated soil near industrial sites and chemical factories, according to Olson and Fletcher (1999) [14].

According to Kimble *et al.* (2002) [11], plants sequester carbon from the atmosphere through photosynthesis, with some of it returning to the soil through plant residue, animal waste, and decomposition processes. Soils play an important role in the global carbon cycle, contributing an estimated 55 to 878 billion tonnes (GT) of carbon to total atmospheric CO_2. Rathore and Srinivasulu (2018) [17] estimate that total soil carbon, including organic and inorganic components, exceeds 2250 GT within the top 1-meter depth of the Earth. Temperate regions, such as Kashmir, have favourable climatic conditions for long-term carbon storage due to low degradation activity during peak cold months. This makes temperate climates ideal for mulberry sericulture, which efficiently utilizes the host plants as feed for silkworm larvae, maximizing their productivity. However, intensive agricultural activity causes plants to act as a nutrient sink, necessitating soil replenishment efforts. Traditional farming systems frequently experience nutrient depletion in the soil, resulting in low productivity. To address this issue several strategies are being investigated to improve soil carbon assimilation in mulberry fields, such as.

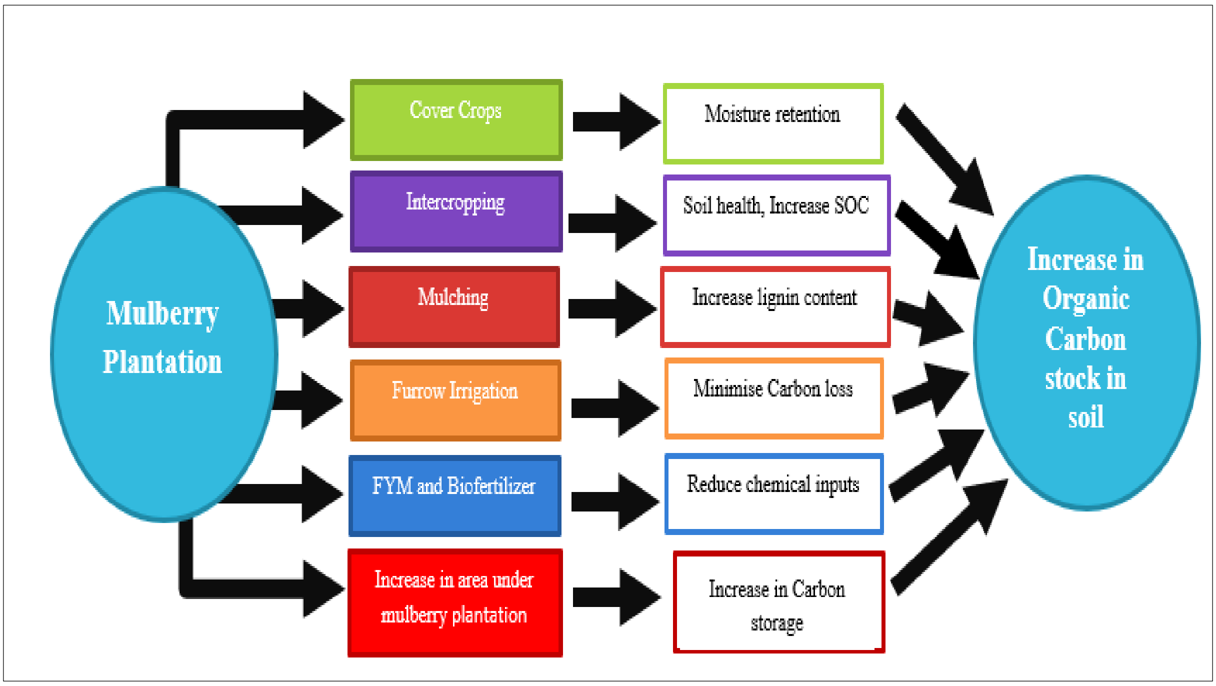

Fig 4: Improved approaches employed in temperate mulberry environments for the sequestration of soil carbon

On the other hand, Kundu *et al.* (2008) [29] and Chauhan *et al.* (2010) [30] discovered that the carbon sequestration potential (CSP) varies depending on the land-use and farming systems used. Furthermore, these techniques not only meet the requirements for food, fodder, and timber, but they also have environmental benefits. This innovative approach, known as carbon farming, encompasses a range of environmentally friendly farming practices such as utilizing cover crops, conservation tillage, pasture cropping, and mulching, among others, which effectively enhance soil organic carbon stock (SOCS). Apart from this, Research by Yadav *et al.* (2020) [25] highlights that cultivation methods significantly impact both the yield and carbon fixation capabilities of mulberry plants. To investigate this, they ran an experiment in red sandy loam soil, comparing traditional mulberry cultivation practices with and without reduced tillage and mulching, as well as two different irrigation methods (drip and furrow). The results showed that the combination of conventional practices, reduced tillage, mulching, and drip irrigation had the highest carbon sequestration potential (CSP) of 15.1 t ha-1 year-1 when compared to the other management practices studied.

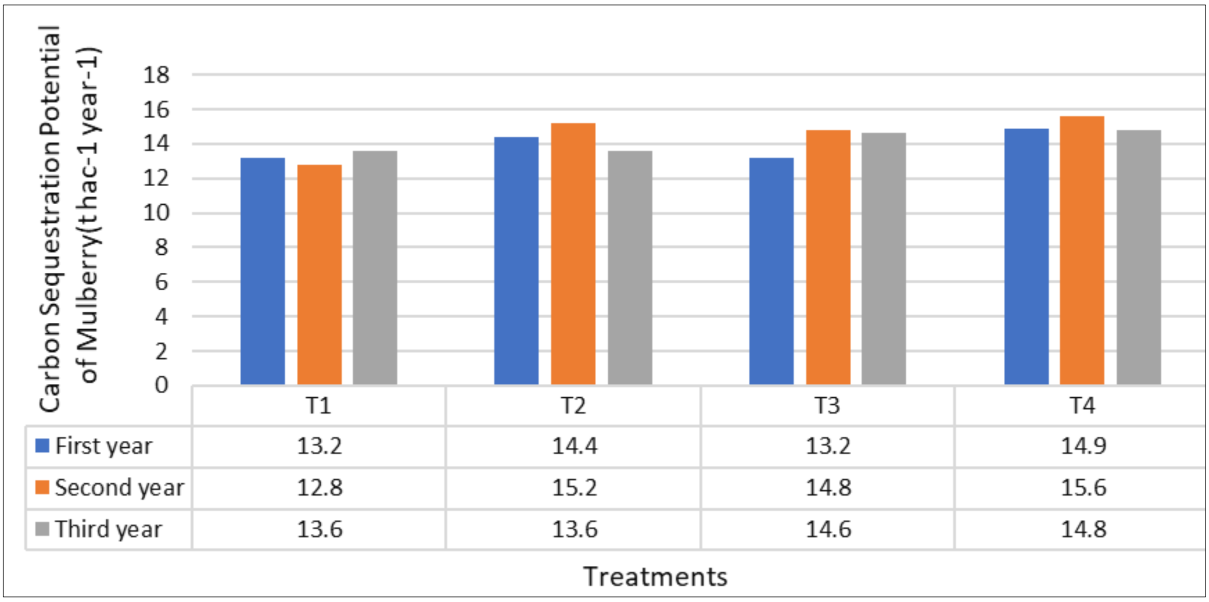

Fig 5: Carbon Sequestration potential of mulberry under the influence of management practices (Yadav *et al.*, 2020) [25]

Conclusion

This review article underscores the remarkable potential of mulberry trees for environmental remediation. Their proficiency in carbon sequestration and air pollutant absorption positions them as valuable tools in the fight against climate change and air pollution. By strategically incorporating mulberry trees into landscapes and optimizing cultivation practices, we can improve environmental quality and contribute to a more sustainable future. More research is needed to investigate the integration of mulberry trees into urban green spaces and to develop large-scale planting programs that maximize their environmental benefits.

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