INTEGRATED FARMING SYSTEMS IN MULBERRY SERICULTURE

Abstract

Integrated Farming Systems (IFS) involve combining multiple agricultural practices to maximize resource utilization, sustainability, and income generation. In the context of sericulture, several IFS options have emerged, linking silk production with livestock, horticulture, agriculture, forestry, artisans, poultry, fungi, and apiculture. These integrated approaches leverage the symbiotic relationships between sericulture and allied enterprises, promoting waste utilization, nutrient recycling, and multiple income streams for farmers. This chapter presents an overview of different IFS options in sericulture, emphasizing their benefits in terms of improved soil fertility, enhanced crop yields, additional income, and sustainable farming practices. The integration of sericulture with diverse agricultural activities opens new avenues for entrepreneurs, supports rural livelihoods, and contributes to environmental conservation.

Keywords: Agriculture, Apiculture, Artisans, Forestry, Fungi, Horticulture, Integrated Farming Systems, Poultry, Sericulture.

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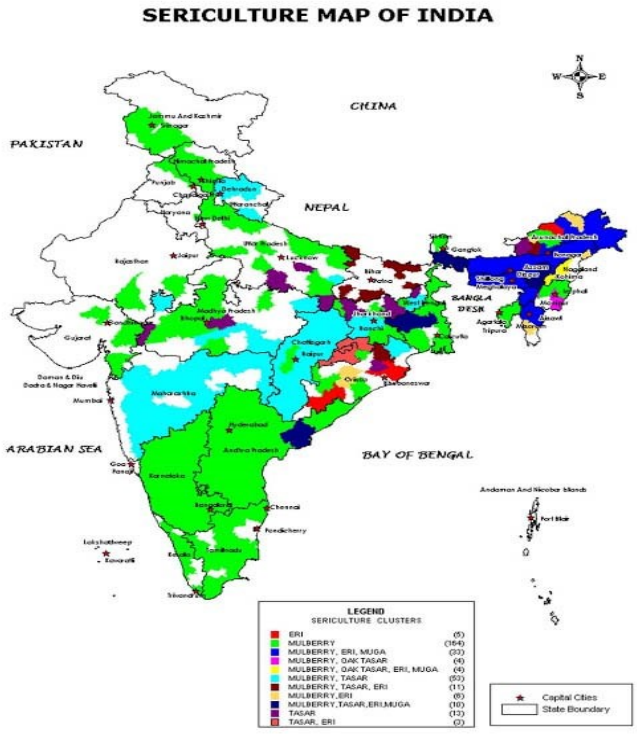
I. INTRODUCTION

Sericulture is an agro-industry; mulberry (*Morus* spp.) cultivation and silkworm (*Bombyx mori* L.) rearing are agriculture in nature, while silk reeling, silk twisting, and weaving activities are industrial in nature. India stands in second place in global mulberry silk production after China with 36, 582 MT (2022–23). The silk industry currently provides employment to 8.8 million rural people in the country. Sericulture in India has proved to be an ideal avocation for inclusive development of the rural populace, especially the weaker sections of society, addressing equity distribution from the urban rich to the rural poor. With its eco-friendly production process and high potential, it became an ideal tool for biotechnological development and a way for women and tribal empowerment. Sericulture stands as a livelihood opportunity for millions owing to its high employment potential, low capital requirements, and remunerative nature.

In addition to sericulture, mulberry has a wide and diverse potential to protect the environment in varying agro-climatic conditions. It is perennial, deep-rooted, widely adaptable, and fast-growing. It produces high biomass and foliage rich in protein. Though it is a medium-sized tree, for intensive cultivation, it is maintained as bushes of different sizes depending on the suitability of the situation. Mulberry can be grown as a tree as well as in combination with agricultural and horticultural crops to increase per-unit area production, as sericulture is a subsidiary crop in sub-tropical areas. Mulberry plant is capable of meeting the present challenges of shortage of fuel wood, fodder, timber, unemployment, cottage industry, environmental degradation, protection and improvement of wastelands, etc. (Rama et al., 2004).



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1. **Seri-Livestock Integrated Farming System**: Two important agricultural practices that can be successfully included in a sustainable farming system are sericulture and animal husbandry. Mulberry leaves are commonly used as the primary feed for ruminants in many regions because they are highly appealing and simple to digest by herbivorous animals. The nutritional status will also improve with the addition of mulberry as feed for cows (Sanchez, 2000). According to Singh et al. (1984), adding mulberry leaves to the diet of Angora rabbits can improve wool output. Mulberry can therefore be used to feed ruminants and other animals during a cocoon price drop, which will benefit business owners even more. Similar to this, waste produced throughout the rearing process (the top layer of new bed waste) can be used to raise sheep or goats. By using the waste, it has been found that 10-12 sheep or goats may be kept per hectare of mulberry garden.

   Even in chawki rearing centre activity, it has been noted that the 1000 DFLs worth of rearing trash and leaf debris produced by chawki is enough to raise 4-5 sheep or goats. Silk and milk go hand in hand because it has been claimed that the utilization of sericulture waste for cattle feeding is a regular practice in several sericulture-intensive areas. In addition to these, the symbiotic relationship between sericulture and animal husbandry also benefits farmers by providing them with feed during dry seasons so that the livestock can survive. Additionally, the mulberry garden uses organic manure made from sheep and goat feces. One tone of manure is obtained in three months for every herd of 15 sheep or goats that are fed in stalls. Additionally, the sheep or goat herds that graze in the mulberry garden after each shoot harvest serve as a natural fertilizer source and prune the mulberry plants. Hence, adopting integrated farming, particularly when combined with crop, dairy, sheep, and sericulture, produced the best results for the farmers in terms of income and employment creation, which was measured at 322 man days annually. Thus, utilizing mulberry as fodder for animals during cocoon price-crash situations can provide additional benefits to entrepreneurs (Nagaraju and Raghavendra, 2016).

   Mulberry can be used in the tropics as a permanent crop integrated into systems of animal production, mainly swines. According to the existing information about the use of mulberry foliage for feeding growing or fattening pigs and pregnant sows, between 20 and 25 % of the ration can be constituted by mulberry foliage. The age of the cut and the handling of plant fertilization are among the factors that can influence the response of the pig herd (Ly and Pok, 2014). Supplementing finisher pig diets with 15% MLP (mulberry leaf powder) improves meat quality traits, possibly through a change in myofiber characteristics, an enhancement of antioxidant capacity, or an increase in intramuscular fat (Zhu et al., 2019). In rice-based diets for pigs, it is possible to use mulberry leaves as the main protein source (Phiny et al., 2003).

2. **Seri-Horti Integrated Farming System:** Silkworm's host plant, the mulberry, can be grown as tall trees in mixed-cropping systems or on the side bunds of vegetable-growing fields. Mango, coconut, and sapota are three horticulture crops that can be easily combined with mulberry production (Kerutagi et al., 2019). Thus, the farmers need not offer their entire land to mulberry production and can make extra money by working part-time in sericulture. Similar to this, introducing floriculture through small nurseries with little time and space offers a major and successful start. The growth of floral crops can be aided by the use of sericulture wastes that have been converted into biofertilizers (Baishya et al., 2004). Cut flowers or the cultivation of flowers like gladiolus, marigold, China aster, chrysanthemums, rose, crossandra, and tuberose can be easily incorporated into IFS. Due to its success in eliminating mulberry nematodes, marigold floriculture provides internal advantages for mulberry plantations (Wang et al., 2007).

Intercropping mulberry with saffron has been demonstrated to produce high-quality mulberry leaves in areas where saffron farming is common, as well as providing farmers with extra revenue during the lean season when there are no saffron-related operations (Kaur et al., 2002). Recent research also suggests that mulberry and medicinal plants, including *Aloe barbadense, Asparagus racemosus,* and *Acorus calamus*, can intercrop well (Madhusudan et al., 2015). The intercropping of mulberry with garlic, onion, carrot, and turmeric was investigated by Singhvi and Katiyar (2009) and Khan et al. (2015), and they found that it not only increased revenue from the production of cocoons but also from the intercrops.

3. **Seri-Agri Integrated Farming System:** Intercropping agricultural crops with mulberry has a number of advantages, including improved benefit-cost ratios, increased yields of mulberry leaves and intercrops, and additional income for farmers. In sericulture, the silkworm *Bombyx mori* L. only feeds mulberry leaves, which account for about 38.20% of a successful cocoon's output. The quality of mulberry is improved by reducing the usage of chemical fertilizers and meeting the nutritional needs of mulberry by intercropping with pulses in agri-farming systems (Qadri et al., 2004; Rajegowda et al., 2020). In addition to preserving soil fertility, intercropping short-duration pulses, including green, black, horse, and cowpea, with mulberry also boosts leaf yield, grain and fodder yields, and supplements bulk organic matter (Babu and Dandin, 2009). The cost of growing mulberry alongside various field crops led to higher benefit-cost ratios in intercrops such as field beans, finger millet, and groundnuts than in mulberry as a monocrop (Shashidhar et al., 2022). However, mulberry and cowpea intercropping produced higher benefit-cost ratios than ragi and groundnut intercropping due to the fact that the soil is more fertile, the leaf and cocoon yields are higher, and there is more income (Rajegowda et al., 2020). Moreover, mulberry and cowpea intercropped at a spacing of 90 x 90 cm from June to August yielded the highest intercrop yields and net profits per hectare (Mishra et al., 2009). The aforementioned information makes it evident that IFS agricultural crops with mulberry cultivation increase productivity, profitability, and food security for the farmer while also maintaining soil productivity through the recycling of organic nutrient sources from the participating businesses.

4. **Seri-Forest Integrated Farming System:** Sericulture-based agro-forestry systems (AFS) have great potential for higher returns (Dhyani et al., 1996). Planting mulberry trees in plains would be connected to Silviculture. The remunerative nature of this seri-silvicultural system will motivate more and more people to go for mulberry plantations, which will help in climate change mitigation since mulberry is a high biomass production tree species utilizing large quantities of CO_2 from the atmosphere and its leaf has quick decomposition after its fall, helping in rapid recycling of carbon back to the soil (Kumar et al., 2019). The *Morus*-based silvi-pastoral system results in the production of about 8000 kg/ha of green tree fodder and 24,000 kg/ha of green grass fodder. Farmers can take three cuts of tree fodder as well as quality green grass fodder during lean period (MoAC&FW, 2021). However, elephants do not feed or damage mulberry foliage (Kumara and Yogendra, 2022). Hence, mulberry cultivation in agro-forestry systems can have various benefits in regions where human-elephant conflicts are common. Mulberry cultivation is also carried out as an intercrop in silver oak, teak, Malabar neem, and etc. plantations.

5. **Seri-Poultry Intergraded Farming System:** Feed accounts for 65-70% of total rearing costs in poultry farming. Animal protein is the most expensive component in poultry feed, accounting for 15% of the total cost. Silkworm pupae are a top-notch source of protein, lipids, and important vitamins and minerals. Therefore, a mixture of silkworm larvae and pupae mixed in the right amounts with other food ingredients can make great chicken feed (Longvah et al., 2011). Thus, sericulture in conjunction with poultry can be seen as one of the most promising technologies for increasing farmers' incomes, as this combination creates opportunities for both small-scale and commercial agriculture businesses, and as a result, this kind of diversification produces fruitful outcomes (Prein, 2002). However, by recycling poultry waste, it is possible to create organic manure that can be used as biofertilizer to promote the growth of mulberry plants. In turn, this will eventually aid the worms in creating healthy cocoons, increasing the farmer's resources and income (Kumar et al., 2012). It has been found that raising domestic and guinea fowl in mulberry gardens benefits mulberry growth through weeding, pest control, and fertilizer effects. The egg Haugh unit was also higher. Moreover, when mulberry leaves were given as part of the feed to domestic fowl, vitamin K1 content increased and the odor of manure decreased. Therefore, it is relevant to evaluate and utilize mulberry as a feed for poultry as well as for the sericulture industry (Machii, 2000).

6. **Seri-Pisi Integrated Farming System:** The integrated farming system of sericulture and pisciculture involves a harmonious combination of mulberry cultivation, sericulture activities, silk extraction, and fish farming. In this integrated approach, each component plays a crucial role: mulberry serves as the primary producer, silkworms act as the first consumers, and fish become the second consumers, directly benefiting from the silkworm. Recent research conducted by Kumar et al. (2012) demonstrated the effectiveness of this system, utilizing silkworm feces, silkworm pupae, and wastewater in fish farming. Notably, trout fish fed with silkworm pupae meal reached a marketable weight of 250 g/fish in just 8-9 months, compared to 12-13 months when fed with traditional feed. This integrated system ensures improved fish growth without compromising survivability. The practice of combining aquaculture and mulberry trees near ponds has been extensively employed in China and has been well studied. This system involves incorporating silkworm droppings, waste pupae, and washings from silkworm trays into the fishponds. This increases the pond mud, or humus, which serves as a valuable nutrient source for mulberry cultivation, contributing to the overall sustainability and productivity of the integrated system (Ruddle and Zhong, 1989; Zhong, 1995). By synergizing sericulture and pisciculture in this manner, this integrated farming

approach presents a promising and environmentally friendly solution for enhancing agricultural productivity and resource utilization.

7. **Seri-Fungi Integrated Farming System:** The seri-fungi integrated farming system combines sericulture (silk production) with mushroom cultivation, creating a symbiotic relationship between the two. In this system, the byproducts and waste materials from sericulture are utilized as inputs for mushroom cultivation, resulting in improved resource efficiency and economic returns. During sericulture, silkworm rearing generates substantial amounts of silkworm excreta, leftover mulberry leaves, and damaged cocoons. Instead of discarding these byproducts, they are repurposed as valuable inputs for mushroom cultivation. The nutrient-rich silkworm excreta, also known as silkworm castings, provide an excellent substrate for mushroom growth due to their high organic content and beneficial microorganisms. About 15 MT/ha of sericulture waste, mostly mulberry shoots, is generated yearly from silkworm rearing (Das et al., 1997), which is a good raw material source for an entrepreneur starting mushroom production in sericulture belt areas. This diverse and integrated utilization of mulberry also enables young entrepreneurs to get additional income from their small piece of land (Amelia et al., 2020). The integration of mushroom cultivation with sericulture offers several advantages. Firstly, it helps in the efficient utilization of waste materials, reducing environmental pollution, and promoting sustainability. The sericulture byproducts serve as an affordable and readily available substrate for mushroom cultivation, eliminating the need for costly or resource-intensive inputs. Similarly, *Cordyceps* mushrooms are the most valuable naturally grown fungus on the surfaces of lepidopteron insects. These Himalayan fungi have high demand in the United States, with a price tag of US$ 2000 per kg in their purest form (Chugh et al., 2022). Because of its scarcity and high medicinal value, artificial cultivation methods on a commercial scale have been developed (Aggarwal and Babu, 2004). In Korea, many cottage industries produce *Cordyceps* in silkworm powder or pupae, which are further utilized as a dietary supplement or culinary ingredient to improve health (Hong et al., 2010). Since India produces approximately 139,162 MT of fresh pupae annually, new entrepreneurs can take up *Cordyceps* production as an integrated approach to enhance profitability. Furthermore, the integration of sericulture and mushroom cultivation can enhance the economic viability of farming systems. The sale of both cocoons and mushrooms can provide diversified income streams for farmers, increasing their overall profitability. By combining sericulture and mushroom cultivation, farmers can achieve enhanced productivity, reduced waste, and improved economic returns.

8. **Seri-Apiculture Integrated Farming System:** The commensal relationship of mulberries with humans is not only restricted to the production of foliage for silkworm rearing and livestock farming, but their floral products have also been efficiently utilized. Since mulberry and non-mulberry food plants have flowers, they are a rich source of pollen, which becomes a potent food source for honey bees (Rijal et al., 2018). Some of the intercropping of mulberry and other agricultural and horticultural plants (pulses, fruits, flowers, etc.) serves as a good source of pollen for honey bees. Therefore, such integrated activities give immense scope for a businessman to take up beekeeping as a subsidiary source of income on the mulberry plantation.

9. **Seri-Artisan Integration:** The cocoon handicrafts have a very good market value, and the handicrafts prepared from the waste cocoons may explore good market potential. However, it is estimated that these cut cocoon byproducts could lead to a value addition of up to 30.0% in the mulberry post-cocoon sector if utilized skillfully with effective management in cocoon crafting, besides raw silk reeling from good cocoons. Cocoon crafting is the art of designing some handicraft products like flowers, bouquets, garlands, greeting cards, and other artistically designed fancy items. These can be decorated in our homes and workplaces to add to their aesthetic look. Cocoon-crafted flowers can be used as ornamentals. Cocoon crafting can be taken as a commercial activity, particularly by women of low socio-economic status, who in turn can bargain a good economic return by simply utilizing cut or pierced cocoon waste with their creative skills. If the development or design of cocoon handicrafts is taken as a commercial activity, it will attract the attention of a huge number of local masses, thereby boosting their revenue returns and value addition in sericulture through the handicraft market (Mandre and Kumar, 2006; Kaul and Pandey, 2014).

10. **Integrating Silkworm Rearing Byproducts for Sustainability:** Integrating Sericulture Byproducts for Sustainability (ISBS) is a crucial approach that recognizes the potential of byproducts generated in the sericulture industry. Waste management and utilization of these byproducts are essential for maximizing their value. The interconnection between

various byproducts obtained during mulberry cultivation, rearing, and reeling in the sericulture process by implementing ISBS, it is observed that high-quality compost can be produced using compost culture, significantly reducing the composting time. It has been recorded that around 12-15 tones of rearing waste are available per year from one hectare of mulberry garden. Using such rearing waste judiciously for *in-situ* composting (trenching and mulching) helps meet up to 50% of the mulberry nutrition annually. The use of compost culture, a consortium of four microbial cultures (*Pleurotos, Phenerochetae, Trichoderma,* and *Pseudomonas*), further boosts the process of decomposition, particularly the lignin-degrading fungi (*Phenerochatae chrysosporium*) which accelerates the activity. It has been very well observed in farmer's fields that only 3-4 months are sufficient to degrade mulberry twigs with the use of compost culture, and without it, the duration is about 8–10 months. The mulberry compost is further supplemented with nitrogen-fixing (*Azatobactor and Azospirillum*) and phosphorus-solubilizing bacteria to formulate Bio-rich' compost. Enrichment with micronutrients like Zn, S, Mg, Mn, gypsum, Bo, copper sulphate, wood ash, and concentrated cakes of pongamia and neem to formulate 'Nutri-rich'. It is observed that application of such compost to mulberry gardens enhanced water holding capacity, leading to better nutrient utility and thus quality leaf production even under water stress conditions, particularly in rained mulberry growing areas of the Eastern Dry Zone in Karnataka. Similarly, various end products are generated at each and every stage of sericulture that can be utilized by vermicomposting, and the vermicompost thus produced can be used for the cultivation of various agricultural crops. It was reported that the average income of farmers increased by 38.31 percent by adopting an integrated farming system involving vermicomposting as an integral enterprise (Kerutagi et al., 2019).

II. CONCLUSION

Integrating sericulture with various agricultural practices through Integrated Farming Systems (IFS) offers multifaceted benefits that encompass resource efficiency, sustainable agriculture, and diversified income sources for farmers and entrepreneurs. By establishing symbiotic relationships between sericulture and other agro-enterprises, such as livestock farming, horticulture, agroforestry, mushroom cultivation, and more, farmers can optimize resource utilization, reduce waste, enhance soil fertility, and increase overall productivity. These integrated approaches not only promote economic viability but also contribute to environmental conservation and rural livelihood sustainability. Embracing the concept of integrated farming systems presents a promising pathway towards a more resilient and prosperous agricultural landscape.

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