**Integrated Farming Systems in Mulberry Sericulture**

**Ravi Kumara R1\*, Harish Kumar J1, and Mohan Kumar G. P2.**

1Department of Sericulture Science, University of Mysore, Mysuru 570006, India.

2Flower and Medicinal Crops Division, ICAR- Indian Institute of Horticultural Research,

Bengaluru 560089, India.

\*E-mail: ravisilkstar5@gmail.com

**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.

1. **Introduction**

Sericulture is an environmental friendly, employment potential, low investment and high income generating enterprise comprising of on-farm (mulberry cultivation), off-farm (silkworm *Bombyx mori* L rearing) and industrial (reeling and spinning of silk) activities. In the quest for sustainable development and ecological balance, the importance of integrating diverse agricultural practices into harmonious agro-ecosystems cannot be overstated. Among the myriad of agricultural pursuits, sericulture stands out as a time-honored practice, boasting a rich history spanning millennia. Sericulture, or the cultivation of silk through the rearing of silkworms, not only epitomizes a remarkable alliance between humans and nature but also exemplifies the potential for achieving synergistic benefits within agricultural landscapes. The inherent synergy of sericulture lies in its ability to intertwine with various agro-ecosystems, contributing to the creation of integrated and dynamic agricultural landscapes. This integration brings forth a multifaceted array of ecological, social, and economic benefits that collectively foster sustainable development at both local and global scales. As we face mounting challenges such as climate change, food insecurity, and biodiversity loss, orchestrating integrated agro-ecosystems becomes an imperative step towards fostering resilience and a regenerative approach to agriculture.

**A. Seri-Livestock Integrated Farming System**

Two important agricultural practices that can be successfully included into 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, 2002; Takahashi 1998; Rohela et al., 2020). 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 (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 chawki rearing centres are using all of the garbage produced during the activity, and 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 utilisation of sericulture waste for cattle feeding is a regular practise in several sericulture-intensive districts. In addition to these, the symbiotic relationship between sericulture and animal husbandry also benefits farm women 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 faecal pellets. 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 fertiliser source and prune the mulberry plants. Additionally, according to Nagaraju and Raghavendra (2016), 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.

**B. Seri-Horti Integrated Farming System**

By increasing the area under cultivation and implementing the concept of mixed cropping, horticulture production can be boosted. 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 dedicate their entire property to mulberry production and can make extra money by working part-time in sericulture. Similar to this, introducing floriculture through tiny 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. In addition, there are further advantages of growing flowers as an intercrop in mulberry fields (Baishya et al., 2004). Cut flowers or the cultivation of flowers like gladiolus and marigold can be easily incorporated into IFS (Kumar et al., 2012).  Due of its success in eliminating mulberry nematodes, marigold floriculture provides internal advantages for mulberry plantations. By acting as a non-host or subpar host, producing toxic or inhibitory allelopathic compounds, fostering an environment that favours nematode antagonistic flora or fauna (Wang et al., 2001), or (4) acting as a trap crop (Pudasaini et al., 2008), marigold can reduce nematode populations.

**C. Seri-Agri Integrated Farming System**

Intercropping in agro forestry systems, which combines sericulture with agricultural crops, 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 eats 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 fertilisers and meeting the nutritional needs of mulberry by intercropping with pulses in agroforestry systems (Qadri et al., 2004). 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). 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). Increased productivity and net returns per unit area of land can be achieved in agroforestry systems by integrating field crops with mulberry (Rajegowda et al., 2020). According to a recent study by Shashidhar et al. (2022), the cost of growing mulberry alongside various field crops led to higher benefit-cost ratios in intercrops such field beans, finger millet and groundnuts than in mulberry as a solitary crop. According to Rajegowda et al. (2020), mulberry and cowpea intercropping produced higher benefit-cost ratios than ragi and groundnut intercropping did because the soil was more fertile, the leaf and cocoon yields were larger, and there was more money.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. According to Mishra et al. (2009), 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. 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.

**D. Seri-Forest Integrated Farming System**

In farm and agroforestry systems, the incorporation of agroforestry practises, particularly mulberry trees, offers a number of advantages. In order to improve nutrient cycling, soil organic matter, soil and water conservation, rural livelihood security, climate change mitigation, sustainable use of natural resources, and greening initiatives in India, these systems involve the inclusion of various trees, shrubs, and plants within farming landscapes. As many as 20 recognised systems in diverse agro-ecological zones make up farm/agroforestry systems, which are made up of numerous components. While providing hedgerows and fencing to protect fields from wild animals and providing food and shelter for wildlife on the outskirts of villages, these systems also cater to the various needs of farmers. In turn, this lessens the severity of conflicts between people and wildlife, especially when valuable cash crops are cultivated close to populated areas. Additional advantages result from combining sericulture (the production of silk) with agroforestry techniques, particularly when mulberry trees are grown. Mulberry trees are useful elements in agroforestry systems because they provide shade, enhance soil quality, stop erosion, and act as windbreaks. In addition to assisting silk production, mulberry planting aids environmental stability and biodiversity preservation. It's interesting to notice that when offered mulberry and other forages combined, wild herbivores strongly prefer mulberry. However, elephants don't typically appreciate mulberry foliage, which may be because the leaves contain special chemical components like morin and -sitosterol that may repellent to the elephants (Kumara and Yogendra, 2022). Mulberry plants' growing characteristics, such as their quick development and resistance to injury, may also play a role in elephants' distaste for them. Mulberry cultivation in agroforestry systems can have various benefits in regions where human-elephant conflicts are common. Growing mulberries offers a perennial, quick-growing, and useful plant with many applications. It is a desirable choice due to its wide range of adaptability and ease of growing. Communities can attain sustainable livelihoods while preventing and minimising confrontations between people and elephants in wooded areas by combining mulberry production for sericulture or other reasons. Conclusion: By cultivating mulberry trees, sericulture and agroforestry can be combined to support the production of silk as well as other advantages including ecosystem stability, biodiversity preservation, and conflict reduction in human-wildlife interactions.

**E. Integrating silkworm rearing by products 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 was discovered 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 (Kallimani *et al.,* 2014). 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, 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. In a study conducted by Kerutagi *et al.* in 2019, 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.

**F. Seri-artisan integration for sustainability**

Aspects of IFS and sericulture were highlighted in several further integrated initiatives involving sericulture and other related agri-enterprises (Baishya et al., 2004). In addition to creating a market for itself, the manufacturing of bio-crafts from cut or pierced cocoons has given rural children and those with disabilities useful skills. Economically, integrating sericulture byproducts has shown higher benefit-to-cost ratios, ranging from 1:1.27 to 1:5.54, showing improved use efficiency for sericulture farmers and business owners. This strategy supports the sericulture sector's steady expansion while enhancing the environment and society at large.

**G. Sericulture and Poultry Integrated farming system**

Sericulture is considered by rural farmers in India to be a secondary occupation. Additionally, the seasonal variations force the farmers to think about different options. For small-scale farmers, the grill or poultry sector is a reliable source of revenue. According to Longvah et al. (2011), 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. 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; AkliluNigussie, 2018).

**H. 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 Sanjeev Kumar *et al.* (2012) demonstrated the effectiveness of this system, utilizing silkworm faeces, 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, more expensive department-supplied 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; Prein, 2002). 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.

**I. 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 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 (Garbyal *et al.,* 2004). In Korea, many cottage industries produce cordyceps in silkworm powder or pupae, which are further utilised as a dietary supplement or culinary ingredient to improve health (Hong et al., 2010). Since India produces approximately 139,162 MT of Mulberry, 18,660 MT of Tasar, and 5,782 MT of Muga fresh pupae annually, new entrepreneurs can take up cordyceps production as an integrated approach to enhance profitability (Anonymous, 2020). Furthermore, the integration of sericulture and mushroom cultivation can enhance the economic viability of farming systems. The sale of both silk 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.

**J .Seri-Apiculture Integrated farming system**

The commensalism relationship of mulberry 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](https://www.sciencedirect.com/science/article/pii/S1319562X21001054" \l "b0305) *[et al.,](https://www.sciencedirect.com/science/article/pii/S1319562X21001054" \l "b0305)* [2018](https://www.sciencedirect.com/science/article/pii/S1319562X21001054" \l "b0305)). Some of the intercultivation farming of mulberry and other crops gram, black gram, horse gram, soybean, and cowpea) 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.

**II. Conclusion**

In 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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