Silk unveiled

FIRST SILK NARRATIVE CATALOGUE

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(Cover Photo / Museo don Mazza di Verona)

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(Photo / **Ž. Sagadin**)

Introduction

The ARACNE project aims to bridge the gap between different European generations. It seeks to connect those who have lived in a world where silk was a part of the agricultural and industrial world and those who have grown up in a technological environment where artificial fibres are the norm.

ARACNE aims to prevent the loss of not only an invaluable heritage of knowledge but also a common cultural basis that can contribute to the growth of a European consciousness. The catalogue 'Unveiled Silk' does not aim to provide an encyclopaedic description of the heritage derived from European sericulture. Instead, it aims to attract and fascinate the reader through images and narrative. While it certainly informs, it also seeks to captivate, impress, and excite. The aim is for readers acquainted with silk to find a world they know, but with the perspective that this versatile fibre can be used in ever more technological ways in the future; and for readers unfamiliar with this world to appreciate the preciousness of its history, the complexity of the production process and the inestimable value for future economic development in a supply chain in which agriculture, industry, tourism, art and science give a formidable impetus to Europe, as has happened in the past.

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The History of Sericulture in Europe

The silkworm was introduced to Sicily and southern Spain by the Arabs between the 9th and 10th centuries and spread to limited areas of the Byzantine Empire more or less at the same time, beginning a process of slow and gradual expansion that was not only determined by environmental factors such as the mulberry climatic limitations.

Mulberry cultivation and silk production proceeded at different speeds and along different paths, the latter often preceding the former by decades, if not centuries, brought about by artisan migrations and mercantile enterprise, while the time required to integrate new plants, animals, cultivation and rearing techniques and practices into local agricultural and peasant culture was much longer. The transition from the use of silk for decoration and embroidery to the weaving of draperies, both plain or embroidered, in the great textile centres of Renaissance Italy - Lucca, Florence, Venice - and in Lyon, destined to become the capital of silk manufacture in Europe, increased the need to import yarns from very distant production areas.

The history of silk in Europe is the story of the gradual "democratisation" of a product that was initially very rare, expensive and exclusive, associated with the sacred and the majesty of the royal power. During the Renaissance, the use of silk became a mark of distinction, first for the high nobility, then for the status of a gentleman, and then simply for a wealthy person. In the mid-15th century, Benedetto Cotrugli warned merchants against wearing silk, but a century later the typical Venetian businessman drawn by Cesare Vecellio in his costume book wore a sober black silk robe.

The propagation of mulberry trees and the rearing of silkworms in the countryside led to an increase in production and a gradual fall in prices, which encouraged the introduction of new types of fabric, less expensive and more exclusive than those of the past, stimulating the rise of new needs and ways of consumption, while the reuse of production waste paved the way for the emergence of a market for popular silk. Product innovation was accompanied by process innovation, with the introduction of new tools, from manual to hydraulic throwing machines and other tools used in finishing, as well as important improvements in reeling machines and powered looms, with the invention of increasingly complex models, until reaching, at the beginning of the nineteenth century, the first numerically controlled machine, the Jacquard loom.

The role played by silk in international trade and luxury consumption led many European states to follow the example of the mercantilist policy developed by Colbert's France, which followed a logic of import sub-stitution, with the creation of royal or privileged manufactures protected by high tariffs or bans on foreign fabrics. Given the impossibility of rearing silkworms locally, as in Prussia or the Scandinavian countries, or the low level of domestic silk production, as in the lands of the Absburgs, the adoption of this policy led to an increased demand for yarns from the Mediterranean or the Far East.

The eighteenth century and the first half of the nineteenth century merge into a single period favourable to the expansion of mulberry cultivation, with episodic setbacks such as those caused in Spain by the Napoleonic wars. Through the individual initiative of landowners and peasants, or with the active intervention of the State, mulberry cultivation intensified in areas where it was already widespread, expanded even in areas less suitable for the growth of the tree, and extended to areas where it was still little practiced, such as Central Europe and the Balkans. On the one hand, the increase in global trade, with the faster and more extensive movement of people, goods, plants and animals, has led to the introduction of new varieties that are more productive or better adapted to specific environmental and territorial conditions, but on the other hand, it has also created the conditions for the crisis in the sector, an excessive concentration of farms and favourable conditions for the spread of diseases, despite the pressure to improve hygiene.

The spread of pebrine from central France in the mid-19th century was, in many respects, a fundamental break in the history of European and world silkworm rearing. Firstly, the repeated failures of silkworm rearing, the increase in costs due to the need to purchase silkworm eggs imported from the Far East or produced by the cellular method, and the fall in the price of silk after the pebrine crisis led to a divergence between those countries and regions that abandoned mulberry rearing in favour of more profitable activities, and those where the activity was still strongly rooted (Northern Italy, Murcia, etc.). No less important, the commitment of scientists and institutions to find a remedy led to a much closer relationship between scientific knowledge and production, with the rise of an industry specialised in silkworm egg production and the creation of research centres specifically dedicated to the study of the mulberry tree and the silkworm and the promotion of rational insect rearing practices, such as those in Gorizia, Padua, Murcia and others.

During the twentieth century, European sericulture had to face a fundamental problem: its nature as a highly labour-intensive activity, increasingly affected by the growth of secondary and tertiary sectors, which led to rising wages and production costs. The crisis of the 1930s, with the collapse of international trade and the division of the world into preferential markets protected by tariff barriers and import quotas, marked the decline of the sector. The emergence of synthetic alternatives, growing competition from Eastern producers and the changes affecting rural society and peasant families made silkworm rearing economically unsustainable even before the introduction of insecticides and pesticides, and highlighted the need for radical innovation to envisage a future for European silkworm rearing.

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Mulberry trees next to the former tavern Štefin in Postojna
Photo / **A. Hodalič**

Production and processing of silk

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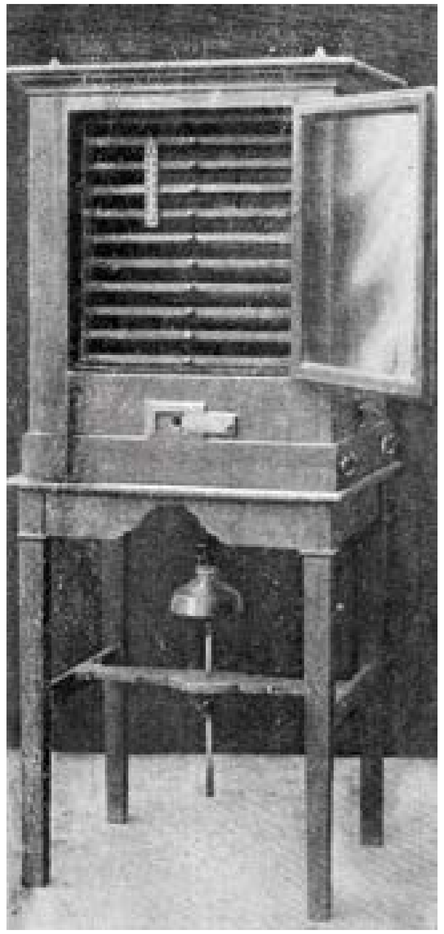
03 | The Traditional Rearing and Sericultural Equipment



One of the first model of incubators used to synchronise larval hatching (incubator Orlandi) (Source / **E. Verson, E. Quajat**, 1896)

Throughout the history of sericulture, a variety of instruments has been developed, which are essential for rearing silkworms and the initial stages of cocoon processing. The equipment for egg hatching is illustrated in the first paragraph. Additionally, practices and tools critical for maintaining the hygiene and health of the silkworms are emphasized, showcasing the importance of a clean and disease-free environment for optimal growth and silk production. This is followed by a review on the assortment of traditional mountages, which assist the silkworms in spinning and forming their cocoons efficiently. In the concluding section, the processes involved in cocoon harvest and the preliminary steps of cocoon processing are detailed, highlighting the intricate and careful methods required to produce high-quality silk.

Incubation of the silkworm eggs

To ensure the simultaneous hatching of the larvae from the eggs and synchronisation with food supply, the eggs are incubated on large rearing facilities in special rooms with controlled temperatures or with the aid of specific tools (incubators). In the past the eggs were usually incubated at home in a warm spot, such as the kitchen, placed under mattresses or even kept in small cloth bags close to the womens' breast. When the eggs and the first life instars of the silkworm were incubated at home, they could also be placed in a kind of tray hanging from the ceiling to prevent the dangerous entry of ants or other predator animals.

Health and logistics of silkworm rearing

For silkworm rearing a diverse range of tools and methods have been employed by the rearers, which vary significantly based on the size of the rearing facility, the quantity and instar of silkworms being reared. Smaller numbers of silkworms are typically housed in appropriately sized containers. Each rearer adopts unique rearing and sanitation practices to ensure the general health of the silkworms. Some use recycled materials, such as cardboard boxes lined with raw paper, as the primary feeding bed for the silkworms. To maintain cleanliness and proper sanitary conditions, these boxes are regularly replaced as the larvae grow. Other rearers may employ plastic boxes. Innovative technologies, including sliding tables and machine-operated platforms, are utilized by some rearers to enhance efficiency. For a more straightforward approach, laying paper and polyvinyl sheets on the ground serves as a simple, yet effective, base for the feeding area.

The health and well-being of silkworms are critically influenced by environmental factors such as humidity and temperature. Traditionally, wood burners were utilized to maintain optimal temperature conditions during sudden drops in external temperatures. Modern practices may involve the use of fans and industrial heaters to precisely control the development cycles and stages of the silkworms. To prevent the desiccation of leaves, special coverings or gauze fabrics are employed.

Historically, wooden shelving systems were constructed to accommodate large numbers of silkworms throughout their lifecycle. These structures featured sturdy upright posts connected by horizontal shelves made from reeds, thin branches, longer boards or even corn stems. To deter ants and other pests, some farmers suspended beds from the ceiling using ropes.

Maintaining cleanliness of the feeding beds is another crucial aspect of rearing. This is achieved by placing perforated paper with holes of varying sizes or plastic nets, according to the size of the larvae, on the beds. Leaves or light branches are then used as cover to let them pass through perforated paper or net, allowing rearers to easily transfer them to a clean, prepared feeding bed or box by lifting the sheet of paper.

However, cleaning with perforated paper or nets requires a lot of labour and manipulation, especially in the last instars. For this reason, sophisticated methods have gradually been developed to avoid bed cleaning by promoting the self-transfer of silkworm larvae from leaf waste to fresh leaves. Some examples of the proposed methods are those conceived by Cavalli, Pasqualis, and Bonoris within the end of the 19th century.

Plastic boxes for silkworm rearing in the first instars. Plastic nets to clean the bedding are visible, too (Source / **Sericulture laboratory of CREA - Padua**)

Typical beds for large-scale rearing of early larval stages. The structures are consist of a wooden frame to which a wire netting is secured and covered with raw paper (Source / **Sericulture laboratory of CREA - Padua**)

a) b) c)

Various methods proposed for silkworm rearing. From left to right: a) Cavallo b) Pasqualis c) Bonoris (Source / **E. Verson, E. Quajat**, 1896)

Perforated sericultural paper with holes in different increments (Source / **I. Bolle**. 1908, p. 21)

Current rearing in a sericultural farm in Northern Italy. 'Pezzone friulano' method (Source / **Sericulture laboratory of CREA - Padua**)

The 'pezzone friulano' method of silkworm rearing, which became popular towards the end of the 1800s, but especially in the 20th century, represented a significant improvement from previous practices that relied heavily on manual labour for the preparation and maintenance of silkworm beds.

The innovation of this method lies in its holistic approach to feeding and caring for the silkworms, by utilizing entire fresh mulberry shoots instead of individually separated leaves. This method involved harvesting whole mulberry shoots and leaning them against a trestle to create a dense, intertwined structure. Silkworm larvae, starting from the fourth instar, were then placed on this structure to feed on the leaves directly. As the silkworms consumed the leaves, new shoots were added to ensure a continuous supply of fresh food. This approach had several key advantages:

The process of pruning branches is significantly quicker than the tedious task of picking individual leaves. This efficiency extended to the rearing process as well, since there was no longer a need to frequently change the beds of silkworms, a task that previously required substantial time and effort. By using whole shoots, the leaves stayed fresh for longer periods. This not only reduced waste but also ensured that the silkworms had access to high-quality food throughout their development, which is crucial for the production of quality cocoons.

Although the Bonoris and Pasqualis methods were based on the same principle, they also focused on saving space, creating wooden structures that were efficient but less? complicated to build and manage. The advantage of the 'pezzone friulano' lies in the simplicity of its structure, which is formed from the mulberry branches themselves and the use of a few other cheap and readily available materials.

The structure formed by the intertwined mulberry shoots facilitated better air circulation within the rearing environment. This is important for maintaining the health of silkworms, as poor air quality can lead to diseases and lower the quality of silk produced. The combination of fresh food, better air quality, and reduced stress from handling likely contributed to health and development of the silkworms.

The 'pezzone friulano' method reflects a thoughtful innovation in sericulture, addressing both economic and biological needs of silk production. It illustrates how agricultural practices evolve not only through technological advancements but also through a deeper understanding of the biological processes involved, leading to more sustainable and efficient farming methods. For this reason, the 'pezzone friulano' method is still used by farmers.

Mounting devices for cocoon spinning

As it comes to devices used to anchor silkworms to supports, so that they can spin the cocoons, there are different options used for centuries in Asia and Europe. The materials used to make these devices vary from natural to synthetic. High-quality feed, optimum environmental conditions and genetic background are the key to first-grade cocoons, which require a perfect shape, size, and cleanliness level. The mounting devices also contribute to silk quality, as they provide enough space and anchorage points for the silkworm to create a first-grade cocoon.

The oldest and simplest form of these devices consisted of bundles of twigs tied together to form upside-down brooms. Twigs used were usually pricked and dried with their leaves. The most common trees were oak, birch, pine and chestnut. Other materials included broom, heather, rape, straw, wine branches, and wood shavings. Branches were placed in bundles or directly on the fresh beds. Sometimes larger rearing cycles required farmers to create special wooden frames which were then covered with branches. They were connected in the form of a tent or just placed against the wall at an angle. In Asian sericulture, circular frames, called Chandraki are used.

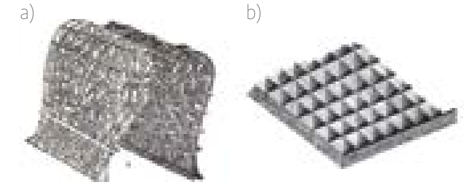
Another mountage form used in the past is colloquially called a hedgehog, because of its spines. This mountage is made with straw being wound and spun together between two lines of wire. From this kind of historic mounting frame, a modern one made of plastic, and called "raggiera" ("sunburst"), was developed. It has the advantages of being reusable, easily washed and disinfected, and also lightweight and stackable.

Other mounting tools developed include egg cartoons and different paper roll tubes, synthetic nets (with hexagonal openings) and paper or cardboard mountages.

The latter are called "Japanese mountages". They have different compartments in which silkworms crawl into and form cocoons. These mountages are especially favoured by the more organised farmers as they are portable, can house many silkworms, provide individual housing for each larva and enough anchoring points for the silkworm to create perfect cocoons. After cocoon harvesting, farmers sterilise the cardboard by passing fire torches to singe the threads that were left behind. These mountages have practically never been used in Europe because of their high demand for labour to be managed.

Silkworm cocoon spinning on the straw mountages in Northern Italy (Source / **Rudolf, Crown prince of Austria** (Kronprinz von Österreich und Ungarn), 1891)

a) b)



Examples of silkworm mounting frames used at the end of the 19th century. a) Ostinelli mounting frame; b) cell mounting frame (Source / **E. Verson, E. Quajat**, 1896)

Current plastic mountages in the shape of "sunburst" (Source / **Sericulture laboratory of CREA - Padua**)

Cocoon harvest and first processing steps

Traditional manual deflossing machine used to remove the floss or the outer silk cocoon layer (Source / **Sericulture laboratory of CREA – Padua**)

The cocoon harvest and initial processing steps are crucial stages in the production of silk. The final phase of the silkworm rearing cycle involves the collection of cocoons after the silkworms have completed their spinning. This usually occurs when the cocoons are fully formed and the silkworms inside have completed the transformation into chrysalis.

Once collected, the cocoons are deflossed, which involves removing the outer, fluffy filaments of the cocoon. These filaments, although part of the cocoon structure, are not suitable for producing fine silk threads. They are removed using specialised deflossing machines to ensure that only the smoother and more uniform layers of silk are left for reeling. After deflossing, the cocoons are sorted into quality grades, the first of which is used for reeling. During this selection process, defective cocoons are removed. Defective cocoons include dead cocoons (cocoons with dead larvae inside), doupions (double cocoons formed by two silkworm larvae) or those that are stained. The cocoons are also calibrated, or sorted by size. In the past, this operation was carried out using a sifting machine, which separated each batch of cocoons according to size: large, medium and small. The machine's two trays, with slatted bottoms, are moved back and forth by a motor so that the large cocoons that fall from the hopper remain in the first tray, the medium ones fall into the second and the smaller ones end up in the third. The selection criteria ensure that only the best quality cocoons are passed on to the next stage, which is essential for the production of high and consistent quality silk during the reeling process.

Cocoon sieving machine (Source / **Museo Abegg of Garlate** (Como))

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Egg laying (Source / **CREA – Padua**)

04 | Mulberries - Living Monuments of Sericultural History

Mulberry trees were appreciated by ancient civilisations like the Persians, Romans, and Greeks, and their presence in Europe increased with the expansion of sericulture from these regions. There is no precise information on when the white mulberry was introduced into Europe and spread in cultivation. It is believed that the black mulberry (*Morus nigra*) was widespread in Europe until the Middle Ages and that the white mulberry (*Morus alba*) appeared in Europe between the mid-6th and 12th centuries along with sericulture.

The tradition of sericulture in Georgia is indeed earlier. Historical accounts suggest that it dates back to the 5th century of the reign of King Vakhtang Gorgasali, who is a seminal figure in Georgian history and is known for founding Tbilisi, the capital of Georgia.

The story of Pyramus and Thisbe is one of the earliest tragic love tales, famously recounted by the Roman poet Ovid in his work 'Metamorphoses'. This ancient narrative, set in Babylon, tells the story of two young lovers, Pyramus and Thisbe, who are forbidden to be together by their parents. Despite this, their love flourishes through whispers, shared through a crack in the wall that separates their houses.

The mulberry tree plays a crucial and symbolic role in their story. Pyramus and Thisbe arrange to meet under a white mulberry tree near a clear spring to finally be together away from the prying eyes of their families. However, a tragic misunderstanding leads to their untimely deaths. Their blood stains the white mulberry fruits red, which is why, according to the myth, mulberries are a deep red or purple colour.

The story of Pyramus and Thisbe, with the mulberry tree as a significant element, symbolises the depth of the lovers' passion and the transformation of the mulberry's colour as a perpetual reminder of their love and tragic end. This tale has inspired numerous works of art and literature through the ages, illustrating the enduring power of love and the capriciousness of fate.

*The Story of Pyramus and Thisbe, David Kandel, 1546 (colour woodcut on paper) (Source / **Hieronymus Bock**, New Kreutterbuch von Underscheidt, Würckung und Namen der Kreuter, so in teutschen Landen wachsen, Strasbourg 1546, folio 343 v.).*

Greece has a rich sericulture history, with references dating back to Theophrastus in the 4th century BC. The introduction of silk-producing insects by Emperor Justinian I in the Byzantine era reflects Greece's deep-rooted sericultural practices and the diversification of mulberry cultivation. Until the 14th century AD, mulberries were mentioned in various texts without a clear distinction between black and white mulberry, leading to some ambiguity in historical accounts. In the 18th century, Joseph Guichard described mulberry cultivation in Chios, then under Ottoman rule, focusing on leaf production for sericulture. In the beginning of 20th century the first detailed description of mulberry varieties in Greece was provided in a textbook on sericulture, describing nine morphotypes ranging from wild and semi-wild varieties to introduced varieties from China and Japan that were propagated by grafting. These varieties were characterised by their fruits, leaf shape, and suitability for silkworm rearing.

Silk production in Sicily (Italy) traces its roots back to the 9th century, initiated by the Arabs who brought sericultural knowledge from Persia. In addition, at this time, cocoons were already being produced in Calabria, where sericulture likely relied on the leaves of black mulberry trees, predating the introduction of the white mulberry in Italy. The earliest record of mulberry leaf harvesting in Italy is by Pier de' Crescenzi in the 13th century in Bologna, and then by Francesco Bonvicino in 1364 in Pescia, who had brought white mulberry plants from the Orient. By 1434, the significance of mulberry cultivation was underscored by the imposition of a tax on mulberry leaves in Bologna, highlighting its economic importance.

In Italy, initially, farmers preferred seed propagation for its perceived advantages in robustness of the plants and leaf productivity, resulting in diverse local mulberry genotypes. Grafting was reserved for valuable or difficult-to-propagate lines, resulting in distinct local and regional mulberry populations. The late eighteenth and early nineteenth centuries marked a shift towards importing new varieties to rejuvenate the genetic background of plantations, to control diseases and pests, and support the move towards specialised mulberry orchards for industrial sericulture. The most extensive and oldest list of varieties is one reported by Jacopo Alberti in 1773, which encloses 22 varieties of white mulberry. Shortly afterwards, the import and study of exotic varieties began, including the 'Morettiana' mulberry, which was cultivated in Milan in 1780 from seeds acquired from India, while the 'Filippine' variety, originating from the Philippines, was already thriving in the Botanical Garden of Padua by the early 1820s, albeit under a different name. Another variety worth mentioning is 'Cattaneo', introduced in 1865 and recommended for the replanting of plantations decimated by diseases. The 'Restelli' variety dates back to the early 1900s. These efforts underscored the dynamic evolution of mulberry cultivation in Italy, laying the foundation for the country's rich sericultural heritage.

First attempts to promote the cultivation of mulberry trees in Slovenia dates back to the 16th century, when sericulture was introduced to the Gorizia region from Friuli-Venezia-Guilia. This influence has later spread throughout the former Austro-Hungarian Empire. The silkworm rearers were initially selling cocoons in the Veneto, especially at the market of St. Lawrence in Udine. The first state incentives, initiated by Ferdinand III, in the mid-17th century, with which aimed to achieve more

Black mulberry
(*Morus nigra* L.)

The black mulberry was brought to Europe from Middle East much earlier than the white mulberry, probably as far back as classical antiquity period. In ancient Greece, the black mulberry was a symbol of wisdom, because of its late sprouting and was dedicated to the god Pan. Black mulberry is quite rare in the continental regions of Europe and the data collected on its distribution is far from complete, whereas genuinely wild populations of M. nigra are quite common in the Aegean and Adriatic region (Browicz 2000).
Its dark coloured fruits can easily be confused with those of the 'dark' genotypes of white mulberry. However, the crown is wider and thicker, and the trunk is twisted and knotted. Young shoots are strong, reddish brown and hairy. Compared to the white mulberry, the black mulberry has a uniformly hairy lower (abaxial) leaf surface. This gives the leaves a silvery shine. The upper leaf surface is dark green and rough. Leaves are broad, heart-shaped. Lobed leaves can also be present but are less common than in white mulberry. The flowers are unisexual catkins. The juicy fruits (soroses) are spherical, 1-3 cm long, greenish when unripe, gradually turning red and later dark purple, and are very aromatic when fully ripe.

A black mulberry (*M. nigra*) shoot with characteristic conical buds, and hairy lower (abaxial) surface of the leaves. Apherical fruits are on short stalk (Scheme / A. Ivančič)

independence from expensive silk imports and reduce cash outflows. A hundred years later, Empress Maria Theresa of Austria and her son, Joseph II. established a state support programme and took the necessary steps to promote their own production of this luxury product. Tree nurseries enhanced mulberry propagation and offered trees throughout the empire, while silkworm rearers were subsidised by the state. The 18th century is known as the 'golden age' of Gorizian sericulture.

Sericulture in Spain evolved from the cultivation of the black mulberry trees, initiated by the Arabs, to a shift towards the white mulberry in Valencia and Murcia in the 16th century, driven by the quest for high quality silk. Over time, two main types of native mulberry trees developed in Spain: the 'Valenciana', a family of genotypes predominant in Valencia, and the 'Cristiana', adapted to semiarid conditions of Murcia. The Sericulture Station of Murcia had been instrumental in spreading these varieties and their hybrids across Spain by distributing 20,000 seedlings to farmers each year. Silkworm rearing in Spain was traditionally integrated into small-scale agricultural systems, with mulberry trees planted at the edges of plots or along irrigation ditches. In Valencia and Murcia, the Huerta irrigation systems, developed by Muslims, supported this cultivation. Additionally, large mulberry plantations owned by the aristocracy, or the church provided another source of leaves for silkworm rearing, suggesting a complex interplay of agricultural practices and sericultural economies across the country.

The history of mulberry cultivation in France has its roots in Roman times, primarily for fruit consumption, with archaeological remains indicating its presence throughout Gaul. The earliest records, dating back to 350/400 AD in the Occitan region, suggest an early peak of mulberry cultivation in the fourth century AD. The hinterland of Nîmes is recognised as the cradle of French sericulture since the Middle Ages, with the Cévennes region playing a central role in linking black mulberry (*M. nigra*) to the silk industry since the 13th century. Olivier de Serres, considered the father of French agronomy, played a pivotal role in the 16th century under the reign of Henry IV by establishing mulberry planting methods to boost silk production within France. This initiative aimed to retain wealth within the country by reducing dependence on imported fine fabrics. Some mulberry trees from this period, known as "Sully" mulberries, still exist in Saint Hippolyte du Fort.

In these countries, mulberry cultivation has evolved from traditional practices to incorporate modern mulberry varieties and technologies. This evolution underscores the enduring significance of mulberries in sericulture, reflecting a blend of historical legacy and innovation within the silk production industry. By focusing on the preservation and revival of this heritage, the ARACNE project aims to foster a sustainable and innovative future for European mulberry cultivation and sericulture.

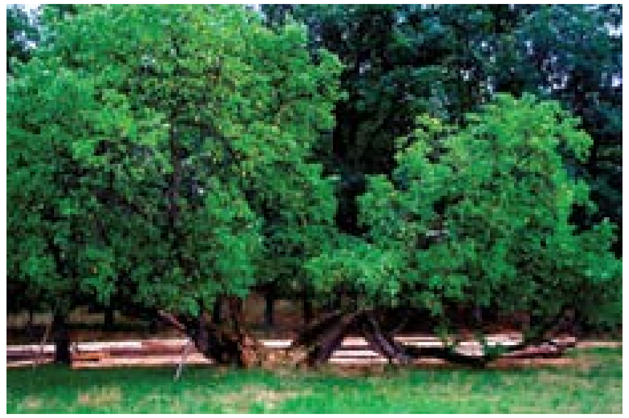
Following mulberry footprints

White mulberry trees can be found throughout Europe, especially in the southern silk-producing countries, where they have been an integral part of the landscape for centuries and bear witness to the former activity of silk production. In European countries, a number of centuries-old mulberry varieties have survived, representing an outstanding natural heritage that reflects past socio-economic and political history. The old varieties are also a valuable genetic resource that is best adapted to specific climatic conditions and can make an important contribution to sustainable mulberry cultivation, to meet the increasing demand of the silk industry.

In Europe, the white mulberry is undergoing dramatic genetic erosion due to the abandonment of sericulture and arable farming, the restoration of agro-ecosystems and the associated afforestation of agricultural landscapes, in addition to the abandonment of the sericultural heritage. Compared to other horticultural crops, where great progress has been made in breeding new varieties using genetic markers, research on mulberries is insufficient worldwide.

The aim of the ARACNE project is to provide an inventory of old mulberry trees in Europe that were associated with sericulture in the past. In addition, the main indigenous mulberry varieties already present in the germplasm collections of the scientific organisations involved in the project or their scientific network will be recorded.

The novelty of the ARACNE mulberry research is the evaluating the existing local gene pool in sericultural regions of the participating countries, which will be compared with introduced cultivars maintained in various germplasm collections. Results of this research will improve their reintroduction and economic value in Europe. In addition, the ARACNE mulberry inventory attempts to underline the need to preserve mulberries as historical vestiges of sericulture in the context of traditional use, which is essential for the future of sustainable European agriculture.



Local black mulberry (*M. nigra*) originated from Eastern Styria, Austria (Photo / **J. Rabensteiner**)

White mulberry
(*Morus alba* L.)

The white mulberry tree originates from China, where it has been widely cultivated for over 4,500 years. It is a deciduous tree that grows to a height of 18 m. The crown is light and circular. The trunk is short and knotted, and the bark is reddish-brown to greenish-grey. Young shoots are yellow-grey and glossy. The leaves are both simple and lobed. The tendency to develop lobed leaves depends on the genotype as well as leaf development, light penetration through the canopy and pruning techniques. The main determinant is the presence of hairs only on the leaf veins on the lower (abaxial) side of the leaves. The white mulberry is more tolerant to pruning, has smoother and softer leaves and is therefore more suitable for sericulture than the black mulberry. White mulberry trees are unique in their sexual expression as their inflorescences are male or female catkins that can occur on separate (male and female) trees or on the same tree, appearing also in bisexual catkins in combinations of both male and female flowers. Male flowers are merged in hanging catkins with 4 stamens, while female flowers are merged into erect egg-shaped inflorescences. The colour of fruits (soroses) varies from white to pink, rarely to dark red.

White mulberry (*M. alba*) shoot with egg-shaped fruits and leaves (Scheme / A. Ivančič)

Morphological differences between white and black mulberry. In the top left, the bud and shoot of the white mulberry and on the right the reddish-brown conical bud and shoot of the black mulberry. The lower (abaxial) side of the white mulberry leaf is glabrous (left) and that of the black mulberry leaf is hairy (right). The different colour types of the white mulberry soroses (photo below left and centre) and those of the black mulberry, which have a very short stalk and a long ripening period (Photo / **J. Rabensteiner, A. Urbanek Krajnc**)

Recreation of landscapes

The 'King' is one of the most monumental mulberry trees in Italy with a circumference of 700 cm from the old mulberry plantation in Vivaro in the province of Pordenone. Most of the monumental trees, the largest of 880 cm, were transplanted from their original location. The plantation survives as a Noah's Ark of old mulberry trees (Photo / **G. Fila**)

Mulberry cultivation and sericulture are being revalued not only for their economic value, but also for their important contribution to landscape conservation and soil improvement, which protects the environment and supports a rich biodiversity. Ancient mulberry trees are ecologically very important organisms. They influence the water regime, carbon storage, nutrient cycling in the environment, and the microclimate regime. Old trees also provide habitat for many animal species. The mulberry tree is an extremely sustainable and versatile species that not only supplies leaves to feed silkworms and livestock, but can also be used for many other lesser-known purposes, such as the production of mulberry tea and the extraction of cosmetic and medicinal ingredients from the leaves, the fabrication of technical goods from wood and wood residues, fruit processing, the preparation of dyes, soil phytoremediation, forestation against erosion, and rural and urban spatial planning. Furthermore, mulberry trees are suitable for planting on polluted areas, around highways and factories and for landscaping in urban areas. The added value is the reduction of noise and improvement of the living environment.

Moreover, mulberries are also associated with the ethnological, historical, and socio-cultural heritage of a particular region. Monumental trees represent a vision of agricultural work as a cultural heritage, a body of knowledge and skills passed down through generations, creating a deep, respectful bond with the land.

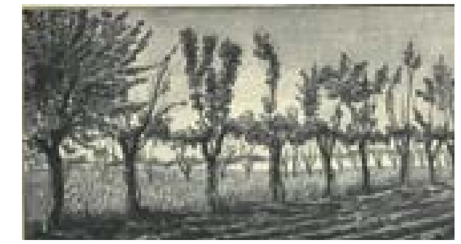
'La Piantata Veneta'

This traditional agricultural landscape showcases an ancient organisation of agrarian space, with roots traceable to Etruscan and Roman times, featuring a diverse cultivation approach known as multi- or poly-cropping. This system harmoniously integrates three types of crops: a shrub-like plant species (commonly grapevine), a supportive tree species (elm, maple, willow, and notably fruit trees such as peaches and mulberries serving as a natural trellis for the vines, while also providing pasture, fruit, or wood), and a ground-level herbaceous crop (such as cereals, vegetables, or a permanent grass meadow). The interplay among these inter-cropped plants creates a synergistic effect, enhancing the ecological efficiency of the system. This not only boosts the biodiversity and health of the ecosystem but also yields significant economic benefits, making it a sustainable model of agriculture that leverages the natural advantages of varied plant interactions.

The unique approach known as the 'La Piantata Veneta', emerged in Italy during the 18th and 19th centuries, incorporating precise hydraulic systems to enhance water balance efficiency. This method is a prime example of multi-cropping, showcasing the innovative ways in which past civilizations engineered symbiotic relationships between plant species for both mutual and economic gains. Designed to maximize harvests across different seasons, this technique was particularly beneficial in times when farmers paid their rent through natural produce to landowners. However, the practice wasn't without its challenges; for instance, poor cereal yields were sometimes a consequence of insufficient manure availability. To mitigate this, legumes and grasses were cultivated together where feasible, enhancing soil fertility and crop productivity. While this approach was economically driven, it arguably offered a more sustainable alternative to some modern intensive farming methods, underlining the historical precedence of ecological and economic balance in agricultural practices.

The transition from a variety of tree species to predominantly mulberry trees was significantly influenced by the silk industry's demand for mulberry leaves to feed silkworms. This shift underscores the adaptability of agricultural practices to economic challenges, while maintaining the essence of traditional polyculture systems. Such systems are highlighted in the scientific and technical literature of the 1800s, with Giovanni Bottari's manuals in the Veneto-Friulian territory and the Carpené Vianello viticulture book of 1874 as well as the autor Wenzel Georg Dunder of the book of Styrian Eden: Savinja Valley and Novo Celje from 1847 providing detailed methods for vine cultivation on trees, demonstrating the long-standing integration of this poly-culture into the Italian agricultural landscape.

The fact that the Superintendency for Historical, Artistic and Ethno-anthropological Heritage for the provinces of Venice, Belluno, Padua and Treviso, in north-eastern Italy, has protected the historical plantation landscape managed by



Mulberry trees used as structural support for grapevines, practice associated with cultivating of the inter-row area with cereals, grasses or horticultural crops. This cultivation system is locally known as 'La Piantata Veneta' (Source / **Rudolf, Crown prince of Austria** (Kronprinz von Österreich und Ungarn), 1891)

Overview of the Silk Hill, with 'La Piantata Veneta' style plantations at Pliuna estate in the Savinja Valley (Source / **Zimmermann**, 2016).

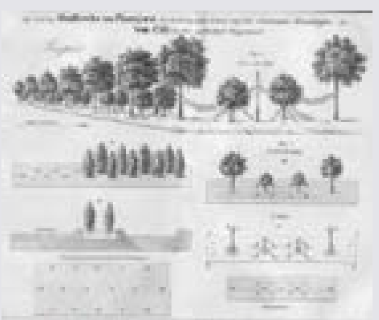
The 'Ancient Vineyard of Baver' in the Treviso province serves as a living example of mulberry-vine association. The traditional agricultural practice 'La Piantata Veneta' (cultivated plots surrounded by rows of vines planted next to tall trees) was included in the Italian National Register of Rural Landscapes with Agricultural Practices and Traditional Knowledge (2018) (Source / **Mario Lešnik**)

the Borgo di Baver Onlus Association since February 2014 as a cultural asset of an ethno-anthropological nature, underscores the value of this cultivation system and the preservation of agrobiodiversity. Moreover, the inclusion of 'La Piantata Veneta' of Baver in the National Register of Rural Landscapes of Agricultural Practices and Traditional Knowledge in 2018 highlights the national recognition of this practice as an integral part of Italy's rural heritage.

The services provided by this poly-cropping systems include wind protection, hydrogeological benefits, wood and fruit production, and the enhancement of recreational and tourism potential. These benefits are anchored in specific agronomic practices, such as strategic planting, pruning, and the avoidance of insecticides, by adopting prevention agronomic measures to ensure the health of both the mulberry trees and the vines.

Taken together, these elements paint a picture of a practice that is deeply interwoven with Italy's agricultural and cultural identity, and demonstrate the enduring importance of traditional knowledge in fostering sustainable, biodiverse, and culturally rich agricultural systems.

The Venetian-Style plantations of Styrian Eden



Scheme of mulberry plantation and tree arrangement at the Mansion Novo Celje (Source / **Zimmermann**, 2016)

The history of mulberry cultivation and mulberry selection in Lower Styria is closely linked to the fascinating agricultural rise of horticultural production at the Novo Celje estate, known as Styrian Eden, which was largely promoted by Archduke John of Austria. In 1843, the owner undertook a remarkable endeavour and initially planted 13,000 mulberry trees on the Plevna estate. Dr Anton Perinello contributed to the diversity of the plantation by acquiring mulberry trees of semi-high and medium height from Lombardy and Rome. The entire Novo Celje plantation consisted of ten large areas, five of which followed the Italian model, supervised by the expert Dr. Antonio de Marco Paolino. It is noteworthy that all Italian mulberry trees of medium and high cut were grafted above the root crown, which is an advanced horticultural technique. These trees were mainly of the 'Giazzola' variety, followed by the 'Filippine' variety, which at that time was considered to have an exceptional productivity and leaf quality.

The Venetian-style plantations, known as 'La Piantata Veneta', were carefully laid out to ensure protection from the wind and provide plenty of sunlight. Mulberry trees were planted in straight rows, alternating between semi-low and high pruning shape, accompanied by selected vine varieties including 'Burgundy' and 'Moselle'. This systematic approach ensured a balance of high and medium trees and a harmonious integration of the vines. The inter-row was used for field crops such as beans which also supplied mulberries and vine with nitrogen.

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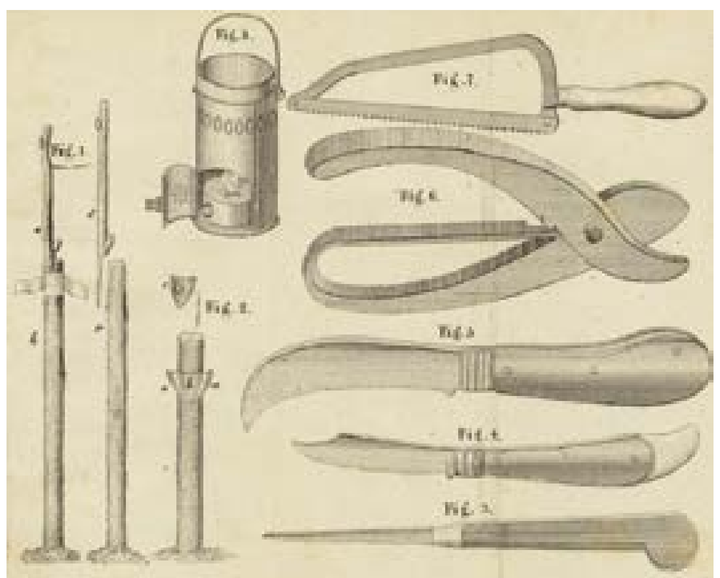
The Fabiani mulberry tree has a circumference of 750 cm and is located on the estate of the famous architect of the early 20th century Max Fabiani in Kobdilj near the old village of Štanjel in Slovenia. (Photo / **A. Hodalič**)

04.1 | The Traditional Equipment used for Mulberry Cultivation

Throughout history, the cultivation and improvement of mulberry trees, pivotal for sericulture, have seen significant developments, particularly in propagation methods to enhance diversity and thus productivity. In the past, mulberries were predominantly propagated generatively, a method that naturally increased genetic diversity within the species. However, specific efforts at genetic improvement through techniques such as grafting were not documented in most countries until the late 18th century. Conversely, grafting of high-yielding mulberry varieties was more common in the warmer regions of Italy, indicating a regional disparity in cultivation techniques.

Cultivation of mulberries requires a range of equipment necessary for propagation, pruning and maintenance of mulberry trees. Propagation, pruning and maintenance description in this chapter is followed by methods used to harvest the leaves and prepare them for the silkworms. This study draws on a wide range of sources, including invaluable museum artefacts, historical and contemporary photographic material and illustrative schemes from books and manuals written by experts from the 17th century onwards.



Pruning tools in the manual of Franz Ksaver Hlubek (Source / **F. Ksaver Hlubek**, 1851)

Tools for mulberry propagation and tree pruning

The propagation process involves the selection of seeds from fully ripe mulberry fruits, which are subsequently dried and stored for spring sowing. It takes two years for the seedlings to become robust enough for grafting. The practice of grafting was adopted to enhance the productivity of wild mulberry plantlets. These wild mulberries usually have strongly lobed leaves, which yield less feed for the silkworms. Grafting, employing knives and adopting methods like shield budding or splice grafting, was performed during dry weather from mid-March to the end of April. Preferred techniques included bark or bark inlay grafting, which facilitated quicker wound healing. After grafting, the mulberries were pruned to a height of one meter and replanted after one year.

The application of grafting resin, a protective measure for large cuts or grafting units, has evolved over time. Historically, a mixture of larch resin, wax, lard, and turpentine was used, and kept liquid over small candle burners. Today, it consists of polymers or bees wax and is conveniently sold in tubes or tins with application tools like special brushes or foam brushes.

Moreover, various tools such as secateurs, pruning shears, and saws have been used for taking cuttings, pruning branches, and shaping the trees. Prevalent forms of mulberry trees in European sericulture utilized the pollarding method, creating semi-low to medium cutting forms. In Italy, the practice of integrating mulberry trees with grapevines, known as 'La Piantata Veneta', has been historically significant and was recognized in 2018 in the National Register of Rural Landscapes of Agricultural Practices and Traditional Knowledge, underscoring its value to Italy's rural heritage.

This method promoted a symbiotic relationship between mulberry trees and grapevines, optimising sunlight and air penetration, and simplifying leaf collection for sericulture. The annual pruning aimed to achieve a uniform branch size and a horizontal crown, maximising leaf production and minimising fruit yield, thereby promoting high leaf yield for silkworm rearing, accelerated growth and sustainability of the trees.

Fertilisation is important to promote mulberry tree growth and high quality of the leaves. Historically, a range of organic and mineral fertilisers have been used on the plantation, including livestock manure, hooves, reeling waste and bone meal. The aim is to provide the plantation with a long-term supply of nutrients. This meticulous care and strategic management highlight the integral role of mulberry trees in sericulture and their impact on rural agricultural practices.

Leaf harvesting and preparation

Leaves are harvested by hand from shoots directly on the tree or from cut branches stored in the shaded part of the rearing area. For taller trees, farmers use a special tool equipped with hooks to pull the branches down. Leaves are stripped from the shoots using sharp knives with a hook on the end, or modified scythes and sickles.

Once harvested, the leaves are transported in specially designed handwoven baskets, containers, or bins made from bamboo or wood. Sometimes, textile bags tied around the waist are used to carry all the harvested leaves. At the rearing facility, leaves might be laid out for drying or stored in a cool, dry area for later use. The harvested leaves are stored in the above mentioned trays.

During the early instar stages of the silkworm lifecycle, young caterpillars are fed on finely cut mulberry leaves. These leaves should be freshly picked, clean, and dry to the touch. The leaves are chopped finely into strips a few millimetres wide using different kinds of knives. Traditional Japanese knives (Kuwakirihochiyo) were large and heavy, but nowadays, rearers use ordinary sanitized and clean kitchen knives dedicated solely to leaf cutting. For larger rearing cycles, farmers used a handmade tool with a wooden box for the leaves and a steel blade with manual movement. Today, specialised cutting devices are utilised for this purpose. For the last two instars, shoots can be directly placed onto the beds with silkworms.

Two wicker baskets with freshly picked leaves ready for to be transported to the growing bed (Photo / **A. Urbanek Krajnc**)

Photo top left: A photograph of a woman using a leaf-cutting machine (Source / **CREA Sericulture laboratory**)
Photo top right: Mulberry shoots are harvested from mulberry trees which form a fence. These mulberry trees are pruned and trained using a special technique called pollarding (Photo / **A. Urbanek Krajnc**)
Photo bottom right: Modern version of a leaf-cutting machine made of metal (Photo / **A. Urbanek Krajnc**)

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05 | Outline of silk processing with brief historic notes

The silk industry consists of a long chain of operations that, starting from the silkworm dried cocoons, the raw material for the silk processing cycle, transforms them into thread and yarns and the yarns into a wide variety of artefacts.

1. COCOON PROCESSING

1.1 Drying

The main objective of cocoon drying is to interrupt the life cycle of the chrysalis which, if it were to become a moth, could emerge from the cocoon by piercing it and disrupting the continuity of the silk filament that makes it up. This would render the cocoon unreelable and turn it into waste. At the same time, drying removes much of the moisture contained in the cocoon and chrysalis, which could lead to mould and decay. Drying therefore preserves the cocoon for subsequent processing and enables long-term storage.

The most common and effective method of drying is hot air drying, in which the cocoons are placed in not too thick layers in a ventilated chamber in which a constant and uniform flow of preheated air is circulated at a controlled temperature so as to evaporate the water contained in the fresh cocoons and prevent it from condensing in the chamber. The temperature of the air used in the drying process is usually quite high at the beginning (from 80°C to 110-115°C, depending on the technology used) and is gradually reduced to 55-60°C over the course of 4-6 hours of treatment. The optimum degree of drying is around 39-42% (residual weight of the dried cocoon in relation to its fresh weight).

Drying temperatures that are too high or too low, as well as uneven drying of the cocoons, may cause problems in the subsequent processing stages due to changes in the chemical-physical properties of the sericin, which may affect the quality of the raw silk produced.

1.1.1 Drying tools

In ancient times, cocoons were dried by exposing them to intense sun for a few days. However, this system is uncertain if the sun fails or its strength is insufficient to bring the cocoon to this temperature. Substitutes such as braziers were then used.

In Italy, until the second half of the 19th century, the most used method was drying in a bread oven, which was filled with cocoons as soon as the bread was removed. From the mid-nineteenth century, the principle of “wet stewing” became widespread, which is based on the double action of heat and water vapor that causes the death of the chrysalis. The most advanced systems made it possible to obtain the death of the chrysalises in 15-30 minutes at a temperature of 90-95°C. This type of drying obtained by means of steam had the effect of preserving the excellent qualities of the silk thread, as the sericin remained very soluble and allowed an excellent result to the reeling.

The cocoons, however, had to be dried for a very long time, with complex turning operations, which required a great deal of labour. Therefore, other models were created, which, to the action of water vapor at high temperature, added a subsequent action of hot air flow which, passing through the mass of the cocoons, allowed them to dry quickly. Subsequently, hot air systems heated to 70-80°C for a few hours were built, in order to bring the chrysalis to death, also obtaining the gradual evaporation of the moisture contained in the cocoons.

In traditional family silkworm rearing, in general, the size of the farms was such that it was not possible to adopt plants for the killing and storage of chrysalises for long periods. The silkworm farmer had to deliver the live cocoons to the reeling plants, which owned the drying facilities. The need to be able to sell the crop before it deteriorated often put the farmer in unacceptable market conditions.

The first applications of the cooperative principle to the drying of cocoons - “certainly a daring idea”, in the opinion of Arrigo Serpieri - took place in the Brescia, Cremona and Venetian areas (Italy) between the nineteenth and early twentieth centuries. Particularly noteworthy was the social structure set up by the Cooperative Dryers.

After the First World War, many cooperative dryers were born in Friuli (Italy), probably taking as a model two cooperative dryers built in the eastern part of the Venetian province, in S. Donà di Piave and Portogruaro, towns not far from the south-western borders of Friuli. The first, founded in 1901, began operations in 1904; the second was established in 1910. A decisive impetus for the emergence of Cooperative societies for drying cocoons was the advent of modern hot air drying systems, patented towards the end of the nineteenth century.

The new hot air flow provided a further advantage: the sale of cocoons was not based on their weight, as was the case before, but on the “rendita” (percentage of silk obtained from a parcel of cocoons). This would have caused farmers to devote care to the quality of the thread, without focusing exclusively on quantity, and at the same time, it would have freed the reelers from the urgency to buy cocoons immediately, taking on a heavy financial exposure.

CREA – Sericulture Lab – Electric cocoon dryer
(Source / CREA Sericulture laboratory, Padua)

1.2 Cocoon cooking

The dried cocoon is characterised by a very compact silk shell made up of overlapping coils of the silk filament laid down by the silkworm, coils that are held together by sericin, a protein with adhesive properties that coats each fibroin filament like a sheath.

The purpose of cooking is to prepare the cocoons for the next stage of processing by softening the sericin layer, which has previously hardened during the drying process. Softening of the sericin is therefore essential for the smooth and progressive unwinding of the fibroin filament from the cocoon surface and its collection into a continuous thread during reeling.

The cooking system process, which is carried out through various passages in water and steam, at temperatures varying between 60 and 100°C, at ambient pressure or under pressure, aims to replace the air contained in the cocoon with water, while at the same time achieving a homogeneous softening of the sericin in the various layers of the cocoon shell, without causing it to dissolve.

The process must be carefully controlled in terms of temperature and duration of the various stages, as insufficiently macerated or over-macerated cocoons can cause a significant deterioration in the efficiency of the reeling process, reducing the yield and quality of the raw silk produced. To evaluate which water temperature and cooking duration should be adopted to cook each lot of cocoons it is necessary to take into account different factors as:

1) the permeability of the cocoon shells;
2) the percentage of sericin content;
3) the procedure used for drying cocoons;
4) the state of preservation of the cocoons;
5) the cocoon shape defects.

A good esteem of these elements results in a smooth reeling and in a decrease of the processing waste.

1.2.1 The ancient and the modern system of cocoon cooking

There are two basic systems of cooking: the ancient 'Top Reeling' or 'Floating System', and the 'Sunken System'. The Top Reeling method involves boiling water directly over an open flame and then immersing a certain number of cocoons in the water for a few minutes using a perforated ladle. When the cocoons appear dull in colour, somewhat translucent, and feel soft and oily to the touch, and the thread separates easily when pulled, they are considered cooked. In this system, cocoons are cooked only until the silk shell becomes wet but remains impervious to water, causing them to float in the reeling basin. The outer layers of the cocoons in contact with hot water cook faster than the middle or inner layers. If the cooking process continues until the middle and inner layers are properly cooked, the outer layer will become overcooked. This can cause the sericin to dissolve or over soften, resulting in the filament coming off in lumps and spoiling the cohesion, lustre, and cleanliness of the reeled silk. If the cocoons are removed soon after the outer layers are cooked, reeling becomes difficult when the middle and inner layers are reached. However, this defect of undercooking can be partially overcome by keeping the reeling water at a high temperature. This adds to the cost and causes other inconveniences to the reeler. In Japan in the early 1900s, a new method was discovered for silk reeling. Japanese reelers found that by increasing the weight of the cocoon and replacing the air inside with water, causing the cocoon to sink (known as the 'Sunken System'), the shell would be uniformly cooked in all layers. This process involves several steps and is still used in large-scale reeling plants today. Historically, as the method involves using steam, it was introduced in the late 19th and early 20th centuries and significantly improved the silk reeling industry.

Cocoon cooking (Source / **D'orica**, Nove (VI), Italy)

1.3 Brushing

Brushing (detail)
(Source / Museo del Baco da Seta, Vittorio Veneto (TV), Italy).

During this phase, the ends of the individual cocoons are located and brushed to remove the rough surface layer of floss, which is intertwined and coarse and does not provide silk for reeling. It is important to note that the silk filament is obstructed by the surface floss layer, making its removal crucial for successful silk reeling. Mechanical or manual brushes are used to rub the cocoons until the end is found. Depending on the type of cooking the cocoons have undergone, the brushing can be strong or light. This process produces and retains silk wastes.

Manual brushing allows for adjusting the brush action as needed, while using mechanical brushes carries the risk of producing more wastes. This operation was carried out manually until the end of the 19th century, by less specialised female workers (often very young girls) using small brooms and hot water (around 60°C), when mechanisation was introduced.

Brushing
(Source / Museo del Baco da Seta, Vittorio Veneto (TV), Italy)

2. REELING

2.1 The reeling process and its evolution

The silk filament is not of constant thickness throughout the cocoon layers. It begins very thin, grows rapidly until it reaches its maximum and then decreases slowly and gradually as it approaches the inner layer of the cocoon. At the end of its work, the silkworm produces a thread so thin that it is no more than one fiftieth of a millimetre. Hence, during the reeling, there is the need to work with several threads joined together until the desired thickness of the thread is achieved. Therefore, reeling is the process of unravelling the silk filaments that make up the cocoon and combining the filaments from several cocoons to produce raw silk yarn. In ancient times, silk fabric was made from floss silk and the cocoon shell, which was spread out by hand after cooking.

Later, the ancient hand reeling system was discovered, which consisted of winding the cocoon thread onto a rectangular reel, turned by the right hand without a traverse. To increase the reeling efficiency the "sitting-type" reeling machine was developed actioned by an engine or, later, the multiplication of the number of reeling reels was studied to improve the reeling efficiency. Multi-end reeling machine were used for this scope.

From the first half of the 19th century, the first steam-powered reeling mills began to proliferate, where steam was used to drive the reels on which the yarn was wound and to heat the reels temselves. Steam increased the speed and quality of production and imposed a minimum size threshold of the reeling plants; in fact, by significantly increasing the fixed costs, it made it necessary to adopt the factory system and forced reeling plants to extend the opening period, transforming reeling from a seasonal process linked to agricultural cycles into a truly industrial activity, and accelerating the concentration of companies and the marginalisation of traditional rural reeling plants. In particular, steam reeling plants were able to use basins with a greater number of reeling ends and offered innovative solutions in the field of reeling, with reels that could be spun in closed caissons inside which the steam pipe ran, heating the inside to a temperature of around 50°C, indispensable for drying the silk thread. However, even before the pebrin, there had been several smaller but equally important innovations in the improvement of yarns, which made Italy the leader in the sector until the outbreak of the First World War. First of all, the introduction of the "tavella" in the Piedmontese reeling plants, which ensured the "croisure" of the different baves, previously achieved by a complex mechanism for crossing the filaments. In raw silk production, the continuing increase of labour costs has mandated automation. Around 1950, the automatic reeling machine was invented, which controls the number of reeling cocoons per thread. Shortly afterwards, it was replaced by a second automatic reeling machine, which could automatically control the size of the reeled thread.

Manual silk reeling
(Source / Orgosolo (NU), Italy)

2.2 The reeling process at the present time

Carding machine
(Source / **Museo "Martinello Ginetti"**, Leffe (BG), Italy)

Carding machine
(Source / **Museo "Martinello Ginetti"**, Leffe (BG), Italy)

Reeling of cocoons after cooking, brushing, end picking
(Source / **D'orica**, Nove (VI), Italy)

Nowadays, the best quality of reeled silk is produced by automatic reeling machines. The high level of automation achieved by the reeling plants makes it necessary to use cocoons that are free of defects and as uniform as possible in terms of size and thickness of the silk shell. The elimination of defective cocoons (double, crushed, stained, mouldy, insect infested, etc.) is carried out before reeling, in an operation called sorting. During reeling the filaments of a certain number of cocoons (usually 8-10; 'reeling rose') are simultaneously unwound and reunited to form a single filament which is collected on a rotating device called a reel. Between 5 and 10 kg of dried cocoons are needed to produce 1 kg of raw silk.

The automatic reeling machine is able to perform a series of steps required for the transformation of the cocoons in the thread, from the automatic feeding of the cocoons to the reels, to the detection of the end of the cocoons, to the matching of the cocoons to the thread, to the replacement of the cocoons in case of exhaustion. The end groped cocoons go to the end picking section and those correctly picked at the end are delivered to the cocoon feeding basket, which rotates continuously around the winding basin on an endless chain conveyor. It is equipped with a series of automatic controls, the most important of which is the device that controls the count of the yarn being formed, capable of correcting deviations in count beyond the permitted limits by acting on the cocoon feeding section. Other control systems intervene in the event of defects or breakages.

The raw silk yarn is then transferred from the reel of the reeling machine to a reel of defined dimensions, which is used to package standard size skeins (180-200 g) for marketing. At this stage, any defects that may have arisen during the reeling process that were not detected at that stage are also eliminated. The silk hanks must be stored away from direct light and heat, in temperature and humidity controlled premises, free from microbial and insect contamination.

3. YARN AND FABRIC PROCESSING

3.1 Pre-twisting processing

Silk skeins (Source / **D'orica**, Nove (VI), Italy)

Rarely raw silk is sent directly to the weaving industry after reeling. The only exceptions to this are some special fabrics which are produced in Asian countries. All the others are processed on twisting machines to meet the different needs of the weaving process, which requires different types of yarn to produce different types of twists: crepes, plywood, wefts, organzines, etc. Before the yarns are twisted, the hanks must undergo certain preliminary operations, some of the most important of which are described below.

OILING / This is a treatment in which oily chemicals are applied to the silk to make it more suitable for subsequent processes. The percentage of sizing applied varies according to the type of twisted yarn to be obtained. The purpose is to soften the sericin and lubricate the yarn to make it better able to withstand the mechanical stresses to which it will inevitably be subjected during the twisting process.

WINDING / The hanks are transported on spools so that they can be threaded onto the spindles of the twisting machine. This operation is carried out on machines known as winding machines. In this process two or more raw silk yarns (but also yarns already twisted) from different spools are parallelised (doubling) and wound onto a collecting spool to facilitate the subsequent twisting operation.

RE-WINDING / When the silk is very dirty or badly spooled, with bad knots in the thread, or when it is necessary to have a perfectly regular yarn, re-winding is used. It consists of transferring the thread from the spools of the tanning machines, on which it is loosely wound, to others on which the thread is tight and taut. Meanwhile, the yarn is passed through the slot of a clearing machine. The mechanical clearer consists of two steel plates mounted on a bronze stand and adjusted to remove dirt, knots, etc. Today, electronic clearers are used.

DOUBLING / This is the process of joining two or more threads together, parallel and with equal tension. Doubling machines are set up so that if a thread breaks, they stop to reknot it.

3.2 Twisting

Some people refer to the simple rotation of the silk fibres during reeling as twisting. This is undoubtedly a misuse of the word; in fact, in reeling crossing, the cocoon filaments are simply wound together so that they stretch and fuse together. The reeling machine does not twist the raw silk yarn as it is formed. The cohesion between the filaments coming from the individual cocoons is ensured by the sericin which, thanks to the temperature (30-45°C) and the aqueous environment in which the cocoons are immersed, maintains a state of softening so that the adjacent fil-

Silk twisting machine – model
(Source / **Museo "Martinello Ginetti"**, Leffe (BG), Italy)

aments are welded together by the tension applied and the passage through the devices guiding the yarn in formation. On the other hand, twisting of a silk thread is said to be the arrangement of the filaments according to a curved geometric line called a helix or spiral. Turning parallel, taut cocoon filaments on themselves in a precise helical arrangement causes radial pressure between them and increases their adhesion to each other. The bundle of yarn becomes stronger the more twists it has received. The purpose of the twist is to give the yarn strength, compactness, elasticity and a cylindrical shape.

Twists are distinguished by the direction of rotation of the fibres. If they are right-handed, they are marked with the letter Z, because the twists go to the right like the hands of a clock, following the centre line of the letter Z. If they are left-handed, they are marked with the letter S, because the torsion loops go to the left in the opposite direction to the hands of the clock, following the centre line of the letter S. The degree of twist of a thread is given by the number of revolutions the thread has made around its own axis in one metre. Different types of yarn are obtained depending on the number of twists, their combination and direction. At the end of the twisting process, the twists imparted to the yarn must be fixed by steaming (or broaching) in an autoclave.

3.3 Main types of yarn

There are four main types of yarns used in weaving:

PILE / A single raw silk thread is given a light twist, 150 to 200 turns, if it is to be used as a weft, or a strong twist, 600 to 1,000 or even 1,200 turns, if it is to be used as a warp.

WEFT / Two or more raw silk threads twisted lightly, usually 120 turns. This yarn is used in the width direction of the fabric and does not require the use of the finest silk.

ORGANZA / Two or more yarns of raw silk that are first twisted, then doubled and then twisted in the opposite direction. It is a very strong yarn that is used as the warp, i.e. the thread that runs lengthwise in fabrics. It must be made from the highest quality silk. There are many possible combinations of organzine, including grenadine (the twisted version is used for silk stockings) and marabou.

CREPE / Two or more yarns are subjected to very strong twists, two or three times in the same direction, up to 3,000/3,500 turns after steam baths that serve to eliminate the curling effect caused on the fibres by the first twists and caused by the elastic properties typical of silk.

4. WEAVING
4.1 Weaving process

Yarns can be made into fabrics by two different processes: knitting and weaving. Knitted fabrics are made by progressively joining together loops and stitches of yarn. This can be done by hand, with needles or crochet hooks, or mechanically on special machines.

There are two ways of using yarn in weaving:

1. as warp threads, those forming the fabric lengthwise, also called chain or simply threads;
2. as weft threads, those forming the fabric in the width direction, also known as weaving.

Fabrics are made by crossing a certain number of parallel warp threads with a certain number of purely parallel weft threads according to precise and predetermined patterns called weaves. Selvedges are formed on the two sides of the fabric where the weft reverses direction.

Weaving takes place on the looms after the threads have undergone some preliminary operations.

Silk loom shuttle
(Source / **Orgosolo** (NU), Italy)

Preparatory operations:

a) A certain number of bobbins on which the thread is wound are placed on special frames called cantres; these allow the warp threads to be unwound simultaneously under constant tension.
b) The warp threads pass from the reed to a special cylinder called the warp.
c) Subbies are sometimes soaked in vats of hot solutions (sizing) and then dried in driers. This is done when it is necessary to increase the resistance of the wires.
d) The warp is threaded into the meshes of the healds and the teeth of the comb. This operation is called drawing-in.
e) The wefts are wound onto spools by machines called spoolers. The spools are inserted into shuttles, which have the task of transporting the weft.

4.2 History of weaving

Weaving was discovered very early by several cultures at the same time. Weaving with a loom spread throughout the world very early (the oldest archaeological traces are in Egypt, dating back to 4400 BC). In addition to being a useful technique for producing consumer goods, weaving is also a means of artistic expression for all civilisations. It has always had a symbolic function and also an expression of cultural characteristics and ethnic identification. One of the most significant was the heddle, a movable rod that raised the upper sheet of warp. In later looms, the heddle evolved into a cord, wire, or steel band, allowing for the use of several simultaneously. The drawloom, which was likely invented in Asia for silk weaving, enabled the weaving of more elaborate patterns by providing a means of lifting the warp threads in groups as demanded by the pattern. Originally, this function was performed by a boy known as the drawboy. However, in 18th century France, the function was successfully mechanised and further improved through the ingenious use of punched cards. The Industrial Revolution was greatly influenced by the inventions of Jacques de Vaucanson and Joseph-Marie Jacquard, who introduced punched cards to program the mechanical substitute for the drawboy, thus saving labour and reducing errors. Additionally, the contributions of John Kay (flying shuttle), Edmund Cartwright (power drive), and others in England played a central role in the development of textile machinery. Modern looms maintain the basic operational principles of their predecessors but have added an increasing degree of automatic operation.

4.3 Fabrics

Silk is presently woven on the most modern mechanic looms. Handloom weaving is still practised in Europe in some countries, for example Romania, for weaving of traditional style cloths, Italy and France, but only for the reproduction, restoration or copying of antique fabrics, especially upholstery fabrics, which can only be woven on traditional looms.

The intersection of warp and weft, according to patterns known as weaves, gives rise to different types of fabrics. The range of possible weaves is vast and some of them are very complex. The interlacing of the threads that form the fabrics are called weaves, of which there four main families:

Canvas weave: this is the simplest weave in which a warp thread passes over a weft thread and then under the next weft thread, and so on.

Twill weave: the weave is characterised by a diagonal appearance due to the longitudinal displacement of the weft threads over the warp threads.

Satin weave: This weave has a particularly light appearance due to the high number and particular length of visible warp ends. For example, a 6:1 satin is a satin where each warp yarn covers six weft yarns before passing under a weft yarn.

Crepe weave: There are many different types of crepe weave, some of which can be very heavy to improve the draping qualities of the fabric itself. All crepes have a characteristic grainy appearance due to the high twist of the yarns from which they are made. Typical silk crepe fabrics are crêpe de chine and crêpe georgette.

5. OPERATIONS CONNECTED TO DYEING

5.1 Degumming

Prior to the actual dyeing operations, the silk must be degummed, i.e. deprived of the sericin, not completely but uniformly, if the success of the dyeing is not to be compromised. In fact, chemical-physical characteristics of sericin and its solubility in the aqueous phase are not compatible with the subsequent dyeing, printing and finishing stages. It therefore follows that it must be removed from unbleached yarns and fabrics as uniformly and completely as possible (degumming) prior to the continuation of the textile processing cycle. The industrial process exploits the different chemical and physical properties of the two silk proteins. While fibroin is insoluble in water, sericin can be easily solubilised by heat with aqueous solutions containing soap, alkalis, synthetic detergents or organic acids. The most common industrial degumming process involves the use of alkaline baths containing soap, especially for batch processes. The degree of degumming determines the classification of silk into three categories: Ecru silk, Supple silk and Cuite silk. Ecru silk exhibits a 2-5% weight loss and resembles raw silk in both hand and appearance. It is treated with a very weak soap solution, with the objective of removing fatty and waxy materials without significantly affecting the sericin. To prevent the loss of sericin during dyeing, ecru silk may be steeped overnight in a 4-5% formaldehyde solution at 20°C or in a 15% solution at 75°C for one hour. For supple silk, the degumming loss is approximately 8-15%. It is mostly used for the weft of the fabric. Cuite silk is completely degummed and is renowned for its distinctive soft hand and high lustre. It is the typical form in which silk is handled. In the case of the degumming of fabrics with plants operating continuously, soap is replaced by synthetic detergents as these are more effective in compensating the acidity of the hydrolysis products of sericin that accumulate in the bath.

When the aim is to degum twisted silk, it should be re-wound from bobbins again to skeins.

5.2 Silk loading

To compensate for weight loss caused by degumming and cooking, the silk may undergo a chemical process called ‘loading’ to increase its weight. If the chemical percentage exceeds 5%, the fibre must be labelled as ‘loaded silk’. It consists of incorporating metallic salts, tannins or synthetic substances into the fibroin. This treatment also ameliorates some physical characteristics of silk. Loading can be equal to the loss of sericin, lower or higher. However, too high loadings can deteriorate the silk quality.

5.3 Bleaching

Although degumming tends to remove most of the coloured pigments that may be present in raw silk, degummed silk is often subjected to a bleaching treatment to obtain bright white tones and/or to avoid altering the shade of dyes used in very light pastel shades. Usually white fabrics undergo bleaching, while printed ones are dyed with a base colour and then printed. To bleach silk commonly hydrogen peroxide or sodium metabisulphite can be employed.

5.4 Dyeing

Dyeing and printing are the operations that, in the language of textiles, 'ennoble' silk. If the silk has not been dyed, the fabrics that come off the looms are not attractive. Only after dyeing, printing and sizing can silk be called the queen of fibres. For a long time, silk was only dyed in thread, and only towards the end of the 19th century did people begin to dye the fabric. The introduction of the mechanical loom for silk and fashion had focused the attention of technicians on the need to dye pieces and prepare them for further processing. Today, yarn is dyed when fabrics of different colours are to be produced, but the fabric is dyed for plain and printed fabrics.

Dyeing is the process of colouring silk by immersing it in an aqueous solution of a dyeing substance that is absorbed and permanently fixed. Dyeing is a complex process that involves uniformly treatment of the individual filaments throughout their entire thickness, rather than just the surface. The attraction between the dye substance and the fibre is known as dye affinity. Silk has hygroscopic properties, which means it can absorb moisture, making it well-suited for dyeing and printing with both natural and synthetic dyes.

Silk is a luxurious and expensive fibre, and the dyeing process is carried out with the aim of improving its intrinsic quality and value. It is important to avoid any physico-chemical damage which may negatively affect the final properties of silk goods (hand, brightness, fastness). This means that each treatment carried out on silk must be controlled carefully, without exceeding the limits beyond which silk fiber can be seriously damaged. The dyeing of silk is a wet process characterised by the following parameters:

- Temperature, which is generally high, ranging from 75 to 90-95 degrees Celsius. Boiling temperature must be avoided because it could be very dangerous in the presence of acid or alkali. Recently, low temperature and cold processes have been developed for silk dyeing.
- Time, which is usually quite long. It is important to consider the time spent at the highest temperature.

The pH value is typically within the range of weak acid to neutral conditions for the application of acid dyes and metal complex dyes. In contrast, reactive dyes require alkaline conditions for the fixation of the dye to the fiber.

5.4.1 Natural dyes

Natural dyes can also be used, but their use is niche, as their performance in terms of color variety, brightness, and colorfastness to light, washing, and sweat is rather limited. Natural dyes have many supporters. Ecologists and nature lovers defend and preach a return to the use of natural dyes. Until a century ago, plants, flowers, barks and shells were the only sources of colour. Through maceration or the work of micro-organisms, indigo came from the ford plant, purple from certain molluscs, red from madder, and so on. Many plants and flowers can be harvested for dyeing throughout the year. The primary colours needed are red, blue, and yellow, which can be used to create a wide range of shades.

5.4.2 Chemical dyes

In 1856, 18-year-old chemistry student William Henry Perkin successfully obtained the first synthetic purple dye for silk. He reacted aniline, sulphuric acid, and potassium dichromate to produce a tarry substance. By extracting this substance with alcohol, he isolated a purple dye which he named mauvein. This discovery was followed by the creation of other synthetic dyes such as dahlia, magenta red, Perkin green, indulin blue, and Martius yellow. Towards the end of the last century, after years of study, the chemical formulae of valuable natural dyes such as indigo, madder, and cochineal were deciphered and synthesized at a much lower cost. Silk is a protein fiber that can be dyed with a wide range of chemical dyes: acid, basic, metal complex, reactive, and vat dyes. Dyeing operations are:

1) Mordeting: the fibre is treated with chemical mordants that facilitate the fixing of the dye. Dyeing bath, the dyeing substance is dissolved in water at a specific temperature.
2) Application of the dye: the fibre is left immersed in the dye bath for the time necessary for the dye to be absorbed.
3) Washing thoroughly and drying.

5.5 Printing

This is the name given to the set of operations that arrive at imprinting coloured patterns on the plain silk fabric. These patterns may be arranged over the entire surface or may be localised in certain areas. Differently from dyeing, in printing the colour is localised and applied superficially, in the form of a thick paste, and fixed with special treatments. Dyeing with printing is an ancient process; it was firstly found in Europe towards the end of the 16th century to meet the growing demand for brightly coloured fabrics from India and the Orient in general. But the real advances came, about a century ago, after the discovery of synthetic dyes.

There are many printing technologies (screen, cylinder, rotary, etc.) and techniques (direct printing, corrosion printing). The colour is applied in paste form, which must have the necessary viscosity to prevent the colour from diffusing beyond the confines of the dishwasher. The dye is applied to the substrate by means of steam (vaporisation), a treatment that allows the dye to migrate from the paste to the fibre. Subsequently, all the accessories of the printed paste (additives and silica) are eliminated by means of suitable washing processes. It is wor-thy of recalling the first processing techniques:

1) Hand printing: this was still the only method used at the beginning of the century. It was done with hand-engraved plates called "planche", first used in a factory in Lyon. Meticulous and slow, this method still retains all its artistic charm.

2) Machine printing: also firstly adopted in Lyon, around 1885, the first mechanical silk printing was carried out using an engraved copper cylinder. Soaked in ink, the cylinder rotated to apply the design to the fab-ric.

3) Frame printing: known as "Lyon-style" printing, this is the technique that has made Como fa-mous throughout the world. The design to be printed on silk is divided into the different colours and a transparency or tracing is prepared for each colour. Each transparency is adapted to the correspond-ing frame, which consists of a metal frame of different sizes on which a gauze coated with a light-sensitive chromium-salt glue is fixed. The painting is left to dry in the dark and then exposed to very strong light, which dissolves the glue only in the area of the polish. A special wash removes the dis-solved glue, while the tracing area is impregnated with the dye. The process is repeated as many times as there are colours in the design. After each painting is laid, the deposited colour is fixed with a special varnish. This system was perfected with the American silk-screen technique, which added speed to precision and made possible the introduction of rotary silk-screen machines.

Today, the use of digital printing for silk screen printing is gradually becoming more widespread. Digital printing (ink-jet process) consists of special plotters, possibly modified for continuous printing on textiles, equipped with heads that, controlled by a computer executing a pre-defined design, shoot micro-scopic drops of coloured ink onto the material to be printed, which slowly move through the ma-chine. The ink is released from the heads in the form of ink rather than paste. The latter would not pass through the nozzles because it is too dense and viscous. The inks used in digital printing are the same as those used in traditional printing.

5.6 Finishing

Finishing is the final stage in the processing cycle the textiles. It is carried out to impart to the fabric the aesthetic and functional properties deemed necessary to effectively meet the end-user's needs.

There are two main categories of finishing: mechanical and chemical, which are complementary to each other mechanical (for example, calendering, polishing, marbling), and chemical (to obtain, for example, stain resistance, antibacteriality, hydrophilicity or hydrophobia, etc.). Mechanical finishing usually change the aesthetics of the fabric, while chemical finishing also influences the functional performance of the treated substrate.

6. SILK WASTE PROCESSING

During the process of silk reeling some wastes are produced, which are the primary source of material for the 'schappe' or 'spun silk' industry. This kind of industry is, therefore, a "circular economy". The modern, or mechanical, spun silk industry almost coincides with the invention of machinery for spinning cotton and wool. Between 1775 and 1779, the "spinning mule", a machine used to spin cotton and other fibre was invented in England, and it is likely that the first mechanically spun silk was produced in England in 1792, using waste from the reeling industry; probably, the spinning machines designed to spin wool and cotton were adapted to spin spun silk. In 1824, the first mechanical spun silk factory was set up near Basel, Switzerland, with Italian-Swiss machinery for dressing (combing), French machinery for preparation and English machinery for spinning. Almost at the same time, the industry developed near Lyon (France). With the invention of the mechanical comb in 1851, a use was found for the noils or short fibres eliminated during the combing of silk, which made it possible to comb and spin these short fibres according to the principles of cotton spinning. The first spinning mill for silk waste was built in Italy in 1854 in Meina, on Lake Maggiore, thanks to the intervention of Camillo Benso, Count of Cavour.

Silk waste comes from three main sources:
1) from silkworm rearing: floss, unravelled cocoons, stained, double or deformed cocoons;
2) from the reeling industry: the first outer layers of the cocoon resulting from cocoon brushing, partially reeled cocoons and the inner part of the cocoon layers remaining around the pupae after reeling are obtained as waste;
3) from the twisting industry: the fibre from tanning, twisting and warping.

There are three main processing steps. Maceration serves to free the fibre from sericin and takes place in soapy, boiling baths. The fibre is then centrifuged and dried. At this stage, the chrysalis residues are also removed by beating, which is done by special machines. Then there is a degreasing step, whereby the chrysalid oil is removed, the destruction of organic substances and, finally, neutralisation with ammonia. Overall, the process is very heavy from an environmental point of view, and this is one of the reasons why it is no longer practised in Europe. It should probably be reviewed in the light of new technologies. After degumming, the resulting bulk of silk fibre may be subjected to cutting operations to equalise the length of the fibres, and is then processed by combing, to parallelise the fibres and prepare them for the subsequent stages of the actual spinning process. The combers used may be either straight or circular. The quality, commercial classification and intended use of tops depend on the average length of the fibres, which can range from 40 to 60 mm (the longer the better the quality). Spinning is carried out in continuous spinning machines called rings that refine the yarn count and give cohesion to the fibres by applying a certain number of twist turns depending on the yarn to be spun. There is then a cleaning, winding and clearing treatment.

7 CONCLUSIONS

The silk industry in Europe is an important and growing sector. It is home to some of the world's largest and most famous silk brands. In recent years, Covid-19 has had a major impact on the European market, in particular, and on the world in general, however, the silk market has been able to regain its former position in full. Silk brands in Europe have competitive strengths as a high production quality, an innovative design and brand recognition in the global market, and finally a strong leadership in high value-added segments. The silk fashion industry is taking steps towards greater sustainability, with companies developing and creating many new products. This demonstrates that Europe is a sustainable and fair market in terms of trade, with silk clothes produced using high-tech methods. The technology developed over the centuries, thanks to the textile industrial revolution, has given Europe a leading position in the field of textile machinery and supports a very high quality of fashion. The most critical challenges for the future should be faced through clear priorities: an ambitious industrial policy, effective research, innovation and skills development, free and fair trade, and sustainable supply chains.

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History of Sericulture in the participating ARACNE countries

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Italy

The sericulture in the past

9th–10th Centuries
Introduction and spread of sericulture in Italy after the Arab conquest of Sicily.

13th century
Transition from silk embroidery to textile production.

13th–16th centuries
Diffusion of innovations in silk production methods across Italy.

15th–16th centuries
Silk manufacturing becomes a major industry.

17th century
Expansion of mulberry cultivation, silkworm rearing, and export of raw silk.

18th century
Acceleration of mulberry cultivation, including in damp plains and large estates, and innovations in silk reeling machinery.

Silkworm cultivation arrived in Italy in the 9th–10th centuries following the Arab conquest of Sicily in the 9th century, as documented in the Cairo Geniza. From Sicily it spread to Calabria under the Normans and to other parts of the South, while in the rest of the peninsula silk processing preceded the appearance and establishment of mulberry cultivation by centuries. In Lucca, Venice and Genoa during the 13th century, there was a shift from embroidery or decoration of clothing accessories with silk yarns to the production of textiles imitating Byzantine or Arabic models. These processes of diffusion of innovations follow a multiplicity of routes, in some cases independent of each other, and if Sicilian craftsmen from Genoa settled in Lucca, for Venice, a direct link with Byzantium is assumed, particularly in the period following the Fourth Crusade.

Secondary migrations, such as that of exiles from Lucca to Venice in the 14th century, contributed to the diffusion and circulation of technical knowledge and figurative models. Silkworm rearing and mulberry cultivation for larval feeding (sericulture) followed manufacturing with a long delay, so that even at the beginning of the 15th century, production in one of the territories of early establishment of this activity in northern Italy, the province of Vicenza, was limited to around one hundred kilograms of yarn per year.

The second part of the 18th and the first part of the 19th century are the golden age of sericulture. The growing incidence in land revenue of the proceeds from the sale of silk induced the owners to devote more and more attention to silkworm rearing. Dandolo's innovative proposals led to a change in the way rearing was conducted, while constructions and restorations of farmhouses were undertaken to make them more suitable for sericulture.

The era of experts and practitioners was replaced by a scientific and technical approach, particularly regarding to the preparation of silkworm eggs, with the spread of cellular reproduction with microscopic selection of healthy moths and the foundation of the "Stazione Bacologica" in Padua as a centre for the promotion of innovations in the sector. While the more advanced areas of Lombardy reacted autonomously to the crisis caused by pebrine because put into practice and improved on Pasteur's own lessons, the "Stazione Bacologica" promoted an action to improve sericultural techniques and knowledge that bore fruit above all in the 'Third Italy' of the Adriatic regions, favouring the formation of silkworm eggs production poles, such as Vittorio Veneto and to a lesser extent Ascoli.

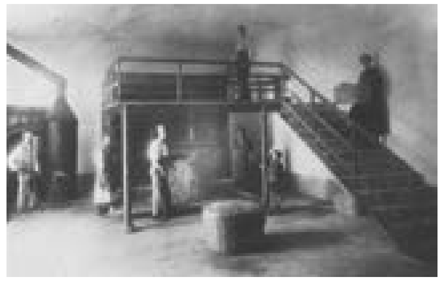
It was in these centres, and especially in the latter, that the production of hybrids was undertaken that would allow Italian sericulture to return to the levels of quality, yields and productivity that existed before pebrine, overcoming the difficulties caused by the import of Japanese eggs.

Farmers transport the cocoons to the collective storehouse to sell them (Source / **CREA Sericulture laboratory**)

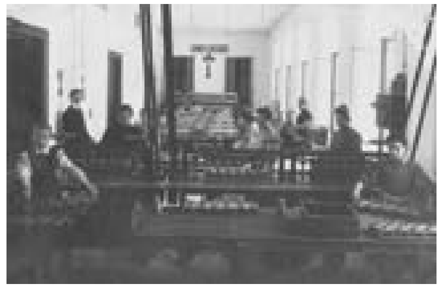
However, from the beginning of the 20th century Italian sericulture was affected by competition from the East, in particular from Japan, where progress in research on hybrids led to the selection of ever more productive silkworm strains, while changes in agricultural structures, with the slow overcoming of the relationships of share-cropping and mixed field rent highlighted the hidden costs of labour-intensive production.

The crisis of the 1930s and the gradual closure of national economies severely affected a sector as strongly export-oriented as silk production was, reducing mulberry cultivation to a marginal role in most regions of Italy. The economic miracle led to the disappearance of silkworm rearing, with only a few restricted areas, such as the Vittorio Veneto district and the upper Friulian plain, where sericulture continued to maintain a residual importance into the 1960s and 1970s.

Egg production plant (moth mating) (Source / **CREA Sericulture laboratory**)



Cocoon drying
(Source / **CREA Sericulture laboratory**)



Egg production plant (moth grinding)
(Source / **CREA Sericulture laboratory**)

Egg production plant (moth eclosion from cocoons
(Source / **CREA Sericulture laboratory**)

The mulberry cultivation

Traditional branch rearing
in a rural environment, early '900s
(Source / CREA Sericulture laboratory)

Mulberry cultivation. Traditional Italian landscape
(Source / CREA Sericulture laboratory)

In Italy, *Morus nigra* was the first species of mulberry introduced, originating from present-day Iran and already known in Roman times. *Morus alba* arrived in Italy later, between the ninth and twelfth centuries, from the Far East, and saw significant expansion around the 15th century.

Even at the end of the 15th century, mulberry cultivation seems to have been scarcely practised in Lombardy, Liguria and Piedmont, while it had already taken hold in Veneto and Emilia-Romagna, in the inland areas of Tuscany, Marche and Umbria and, of course, in Sicily, Calabria and the area between Naples and Salerno. In the late Renaissance, mulberry cultivation was concentrated in hilly and foothill areas, with much rarer and sporadic presences in the lower plains and was almost completely absent from coastal or excessively humid areas. Mulberries are mostly cultivated as isolated plants, placed near farmhouses or along boundary hedges, with only a few trees per hectare, which are perhaps allowed to grow to a much larger size than was usual in the 19th and 20th centuries.

During the 17th century the diffusion of mulberry trees and silkworm rearing continued to increase, becoming inextricably linked to intercropping and share-cropping, and at the same time exports of raw silk to the major traffic centres and manufactures in northern Europe grew. The mulberry tree, however, remained mainly concentrated in hilly and foothill areas. In the 18th century, on the other hand, its spread accelerated, with an increasingly dense presence of this tree cultivation even in areas of damp plains and large estates. From this period onwards, the mulberry is progressively found combined with vines in the planting rows.

The second half of the 18th and above all the 19th century were the period of maximum development of mulberry cultivation, which expanded even in areas with little vocation such as irrigated areas, e.g. the Polesine, and saw the multiplication of plants on the dry plain farms. This process is accompanied by progressive changes in the cultivation of the plants, which are subjected to more intense pruning to limit their growth and make it easier to harvest leaves during the periods of faster growth of the worms, while new varieties are introduced that are more productive or considered more suitable than the traditional ones for damp and clayey soils.

Right: Traditional Friulan branch rearing in a rural environment, early '900s
(Source / CREA Sericulture laboratory)

Silk manufacturing and industrial silk production

Great twisting machine (inner view) Abbadia Lariana (Source / Monti Silk factory)

The development of manufactures was accompanied by important technical innovations, such as the circular twisting machine that appeared in Lucca in the 13th century and the hydraulic twisting machine developed in Bologna in the 14th–15th century.

Between the 15th and 16th centuries, silk processing established itself as one of the main manufacturing activities in the main centres of the peninsula, from Milan and Florence to Naples, and was also introduced in numerous medium-sized towns. Production diversified, from fabrics worked with gold and silver to velvets and damasks, to lighter flat textiles, and the manufacture of silk waste gained prominence.

The instruments used for reeling silk also evolved, with the transition from the large reel spinning machine typical of the South to the low reel spinning machine used in the Centre-North, leading at the end of the 17th century to the introduction of the Piedmontese reeling machine, characterised by the movement of the reels by means of gears and the crossing of the threads.

At the same time there was a process of thinning of the silk thread, made with a decreasing number of silk filaments, technical and organisational/managerial innovations that favoured the production of a more homogeneous yarn and improvements in twisting that made it possible to obtain a thinner and lighter product than in the past but just as, if not more, resistant as the Piedmontese organzine.

At least in part, these innovations are linked to the close relationship established during the 18th century between the Piedmontese silk factory and the Lyon silk manufactory, the most important and advanced in Europe, while other manufacturing regions that were aimed at satisfying demand from other northern countries remained tied to traditional techniques.

The first decades of the 19th century, between the Napoleonic wars and the Restoration, saw the definitive crisis of the remaining Italian silk manufactures, while with the transition from circular to rectangular twisting machines, even this phase of production gradually moved abroad.

The spread of pebrine in the 1850s marks a caesura in the history of Italian silk production in several respects. It opened a phase of crisis and transformation that changed the geography of production, with the abandonment of the activity in the South and its decline in most of the regions of the Centre, while in the North the balance changed between the western regions that were beginning to industrialise and those in the North-East where production was concentrated and intensified.

Difficulties that in the second half of the 19th century favoured the gradual replacement of direct-fire reeling with steam reeling, concentrated in new large reeling mills.

Late 18th-19th centuries.
Peak of silkworm rearing and introduction of more productive mulberry varieties.

Early 19th century
Crisis in Italian silk manufacture, production moves abroad.

1850s
Beginning of the pebrine crisis, turning point for Italian sericulture.

1871s
Establishment of the Stazione Bacologica Sperimentale in Padua, marking a shift towards scientific approaches in sericulture.

1930s
Economic crisis severely affects the entire silk sector.

1960s and 1970s
Disappearance of the silk industry in most Italian regions.

Great twisting machine (outer view) Abbadia Lariana (Photo / Monti Silk factory)

Water wheel – Abbadia Lariana (Source / **Monti Silk factory**)

The sericulture after 1990

In the early 1990s, coinciding with a rise in the international price of silk, there was an attempt to revive sericulture in Italy. However, in 1989, an active ingredient, fenoxycarb, trade name Insegar, was registered in Europe especially for the control of Lepidoptera Tortricidae in apple trees. This insecticide, a juvenile hormone analogue, drifted onto the mulberry leaf and resulted in the so-called 'non-spinning syndrome of the silkworm'. The results of the research carried out by the CREA Sericulture Laboratory of Padua revealed that, within 4 hours of treatment and at a distance of 6 km, the amount of fenoxycarb detected was around 50 ng/square metre panel and ranged from 0.30 to 0.42 ng/cubic metre in the air. These quantities are much higher than those sufficient to prevent the completion of silkworm metamorphosis and estimated at 1x10-3 pg/square metre of leaf. Unfortunately, pollution in the spring season, and the lack of decisive policies on the part of the Italian Ministry of Health to contain the problem, meant that, until the EC's ban on use and the exhaustion of stocks of the product, silkworm rearing was no longer possible in northern Italy, the area where silkworm farmers and plantations were traditionally concentrated, for almost 20 years.

The resumption of activity occurred starting from 2012, through a series of projects financed by various Italian regions, first and foremost the Veneto Region, which led to the establishment of the first operational group on mulberry cultivation 'Serinnovation' (2018). Throughout this period (from the 1990s to now) CREA of Padua has continued to perform research and important goals have been achieved:

1) an Italian patent on artificial diet (2004)
2) collaboration with the company D'orica, born for the resumption of an Italian yarn production with the aim of producing silk and gold jewellery from "made in Italy" cocoons (2014);
3) a specification for organic silkworm rearing with organic silkworm egg production (2015);
4) a traceability system for silk to work with companies that use silk for biomedical production;
5) several prototypes for mechanising rearing (e.g., machine for cutting the leaf for the first three larval ages; machine for harvesting mulberry branches in the 'low-pruned' mulberry field; machine for automatic cocoon deflossing).

Leaf cutting machine for the early larval instars
(Source / **CREA Sericulture laboratory**)

Cocoon deflossing machine
(Source / **CREA Sericulture laboratory**)

Non-spinning syndrome caused by the juvenile analogue 'fenoxycarb'
(Source / **CREA Sericulture laboratory**)

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Bulgaria

Sericulture in the past

Silkworm larvae were fed with whole branches at the beginning of the 20th century (Source / SES-Vratsa archive)

It is assumed that sericulture was introduced to Bulgaria at the times of the first Bulgarian Kingdom, by King Simeon the Great, at the end of 10th century AD. The Spanish traveller Tudelski wrote in the 12th century that sericulture was so well developed on the Balkan Peninsula that the cities were full of silk.

In the 40's of the 19th century there were already 50 silk reeling units in the Vratsa region. The raw silk produced was of two types: the prevailing so called 'burundjuk', a thin raw silk, and the less popular 'kazas', a thicker denier coarse raw silk. The raw silk, produced in Vratsa at that time was considered to be of the highest quality and a part of it was exported to Italy and France.

Wearing of silk cloths was not only fashionable, but silk was also considered to have protective powers, because people believed it was blessed by Mother Marry. For this reason, silk was used to make wedding gifts, baby's caps, to tie the umbilical cord in newborn children, to pierce the ears of young girls etc.

Cocoon harvesting, 1928 (Source / SES-Vratsa archive)

Cocoon harvest from the White Baghdad race, 1940s (Source / SES-Vratsa archive)

Young lady, dressed in everyday dress in front of cocoons spun in tree branches, natural mountages, 1930s (Source / SES-Vratsa archive)

The most common way of incubating silkworm eggs was for the women to wrap the eggs in a thin cloth and keep them in their bosom. When the silkworm larvae began to hatch, they opened the cloth and placed it on a table, then put some fresh nettles on the larvae in order to prevent them from crawling. After all the larvae had hatched, they fed them with mulberry leaves. The mulberry leaves were picked from the trees only in the morning after the dew had risen and collected in baskets, which were woven from vine shoots. Even the style of the houses was adapted to silkworm rearing needs: houses had two floors and the second one was used for silkworm rearing. In the 19th century several million of mulberry trees were planted in Bulgaria.

At that time, the sericulturists believed that the silkworms did not get sick because of diseases, but due to a "remembrance" of some bad persons. Therefore, during the period of silkworm rearing, they protected their worms from 'bad eyes' or 'bad looks' by forbidding other people to enter in the rearing house. However, after 1870, due to the pebrine disease spreading, cocoon production in the present Bulgarian territories dropped about 10 times. During the Russian – Turkish-Bulgarian War of liberation in 1877–1878 many mulberry trees were cut. After this war, there was a mass migration of the Bulgarians of Turkish nationality to Turkey and the labour force decreased. In 1880, due to these reasons and the pebrine disease spreading, sericulture almost disappeared in newly liberated Bulgaria.

10th century AD
Introduction of sericulture in Bulgaria.

1840
Boom in cocoon and domestic silk production.

1886
291 tonnes of fresh cocoons were produced.

1895
The first silkworm eggs were produced by Pasteur's method.

1896
The Sericulture Experiment Station in Vratsa was opened.

1902
1,000 tonnes of fresh cocoons were produced.

1929
2,400 tonnes of fresh cocoons were produced.

Local silkworm breeds and egg production

The local egg production by Pasteur's method started in Bulgaria in 1895 when 2100 boxes (12 g) were produced. In 1896 the Sericulture Experiment Station was established in Vratsa with the main task to control the quality of imported and locally produced silkworm eggs. The largest local production of silkworm eggs was reached in 1926, when 214000 boxes (12 g/each) were produced. After 1931, local egg production was stabilised for a long period of time at around 125000 boxes (12 g/each) per year. Since 1896 the Sericulture Experiment Station in Vratsa has organised many training courses for silkworm egg producers. At the same time some egg producers completed training courses in the sericulture stations of Bursa, Montpellier, Padua, Ascoli Piceno, Tbilisi, etc. Until 1947, local egg production was in the hands of 60-85 local private producers. In 1947 the 'Cooperative of Bulgarian silkworm egg producers' was created and in 1950 the whole egg production was taken over by the state enterprise "Textile fibres". Egg production was centralised in 4 large factories. In 1996 the egg production factory in Vratsa with the Sericulture Experiment Station was moved to the Agricultural Academy and the other three factories were closed.

Since the beginning of local egg production by Pasteur's method in 1895, only two local silkworm breeds have been reared in Bulgaria, namely Yellow local and White Baghdad. The origin of the Yellow local breed is supposed to be the local race spread in North and South-West Bulgaria in the 16th–19th century. The White Baghdad originated from Asia Minor.

The Yellow local race was reared all over North and Southwest Bulgaria. The Yellow local breed is characterised by yellow cocoon colour and cocoons with elongated shape with slight constriction.

The White Baghdad race was reared in Southeast Bulgaria and consisted of 3 types, namely Edirne type, Improved Bulgarian type, and Bulgarian type. The cocoon colour of the White Baghdad race population varied from snow white to light green. The cocoon shape was elongated with a constriction. The local silkworm races were mostly grown as pure breeds until the 60s of the 20th century, after which they were gradually replaced by white cocoon hybrids.

Silkworm egg production in the 1930s (Source / **SES-Vratsa archive**)

Silkworm egg production, 1930s (Source / **SES-Vratsa archive**)

1948
The State Enterprise "Textile fibres" was established, with branches in all cocoon production regions.

1953
The peak of cocoon production was reached, when 3,019 tonnes of fresh cocoons were produced by a country of about 7 million inhabitants.

1989
1,500 tonnes of fresh cocoons were produced.

1995
150 tonnes of fresh cocoons were produced.

2000-2002
TCP project 'Rehabilitation of sericulture in Bulgaria', financed by FAO.

2001
Equipping of Sericulture Experiment Station Vratsa with cocoon dryers, multi-end silk reeling machines, machines and equipment for silk processing and knitting.

2008
Sericulture Experiment Station (SES) Vratsa became a state enterprise under the Agricultural Academy.

2018
Transformation of Sericulture Experiment Station into a Scientific Centre of Sericulture (SCS) under the Agricultural Academy.

Local mulberry cultivation

Mulberry bush type plantation in the 1st year after planting at the Sericulture Experiment Station in Vratsa, 1930s (Source / **SES-Vratsa archive**)

Old mulberry tree near Vratsa, 1930s (Source / **SES-Vratsa archive**)

Mulberry leaves collected and cut to feed silkworm larvae, 1950s (Source / **SES-Vratsa archive**)

Most of the surviving old mulberry trees have small lobed leaves, but there are also some trees with larger, unlobed leaves. Most trees are from seedlings, obtained through open pollination.

The first official import of 12 mulberry varieties was made in 1930 from Italy. In 1932, the staff of Sericulture Experiment Station (SES)-Vratsa visited many places in the South-eastern region and in the Vratsa region to select some promising mulberry trees. Furthermore, many mulberry individuals were collected/created and studied, resulting in the creation of the highly productive Bulgarian cultivars such as Nº24, Vratsa 1, Vratsa 18, Vesletz, Trakia 6 etc. At present, there are 97 Bulgarian native mulberry varieties which are preserved at the Scientific Center for Sericulture, Vratsa Germplasm collection.

In Bulgaria mulberry trees had traditionally been planted mostly as single high–stem trees along the roads in the villages and towns. In1990 there were about 1.6 million such trees all over the country, and now their number is about one million. Some mulberry plantations have also been established. Most of them have 3,330 trees per one hectare with a planting distance of 3 x 1 m and a trunk height of 0.6 m.

Transition from home silk manufacturing to industrial silk production

The first statistical data about fresh cocoon production in Bulgaria date back to 1886, when 291 tonnes of fresh cocoons were produced. For a period of 12 years, from 1890 to 1902, the fresh cocoon production in Bulgaria was increased significantly and reached about 1,000 tonnes per year. In 1929 the fresh cocoon production in Bulgaria reached 2,400 tonnes. An analysis of the Bulgarian export trade in 1928 showed that the dry cocoons occupied the 4th place by value among the Bulgarian exported goods. During the period of 1925-1929 the number of sericulture households was 70-80,000.

After 1930, dozens of silk reeling mills were established in Bulgaria, which started to reel all the cocoons produced. At the same time some silk weaving mills were also established. To stimulate the local silk industry development, the government imposed protective duties on imported silk goods. For a comparatively short period of time during the 30s of the 20th century a considerable silk industry was established in Bulgaria.

After 1944, when the political system in Bulgaria changed, cocoon production remained in the hands of small farmers, but the production of mulberry saplings and silkworm eggs, cocoon purchase, silk reeling and processing were completely

Right: Manual silk reeling tool, used at the end of the 19th century (Source: Vratsa's Ethnographic Museum). Left: Improved Vratsa's type manual silk reeling tool, beginning of the 20th century (Source / **Vratsa's Ethnographic Museum**)

Right and left: Home manual wheel for silk twisting, first half of the 20th century (Source: **SES-Vratsa Sericulture exhibition**)

Silk fabrics weaving handloom, second half of the 19th century (Source: **SES-Vratsa Sericulture exhibition**) taken over by the government. The peak of cocoon production was reached in 1953, when 3,019 tonnes of fresh cocoons were produced by a national country's population of about 7 million inhabitants.

In 1948 the state enterprise "Textile fibres" was established with branches in all cocoon- producing regions. Gradually this company took over the whole sericulture production chain – from science to silkworm egg production, sericulture equipment production, silkworm egg incubation and larvae distribution to producers, mulberry sapling production and distribution, cocoon purchase and processing.

During the period 1950–1990, sericulture farmers in Bulgaria received free mulberry saplings, freshly brushed larvae, chemicals for disinfection, and perforated paper for bed cleaning from the government. A larger part of the costs of cocoon purchasing from the farmers was paid by the government as a subsidy, resulting in a comparatively cheap and stable price for raw silk, fabrics, and garments.

With an average annual production of 1,200-2,000 tonnes of fresh cocoons in the period of 1975-1990, Bulgaria used to occupy the first place in Europe and the 7th-8th place in the world.

Cocoons, spun on natural mountages at SES - Vratsa, 1950s
(Source / **SES-Vratsa archive**)

Feeding of silkworm larvae at SES-Vratsa, 1950s
(Source / **SES-Vratsa archive**)

Seed cocoon sorting, 1950s
(Source / **SES-Vratsa archive**)

The silkworm egg production factory in Vratsa's building, 1970s
(Source / **SES-Vratsa archive**)

Celebration of 100th anniversary of the Sericulture Experiment Station in Vratsa, 1996
(Source / **SES-Vratsa archive**)

Part of the staff of the Sericulture Experiment Station in Vratsa in 1971
(Source / **SES-Vratsa archive**)

Advertisement of the Sirma JSC silk factory, Plovdiv, 1990s
(Source / **SES-Vratsa archive**)

Sericulture after 1990

Silkworm feeding on artificial diet at the Scientific Centre of Sericulture, Vratsa, 2012 (Source / **SES-Vratsa archive**)

However, with the change of the political and economic system after 1990, the cocoon and silk production started to decline sharply. The main reasons for the dramatic decline in production were the price of raw silk being too low on the international market as well as the changes in the political and economic system in Bulgaria.

Another factor that had a negative impact on the situation in Bulgarian sericulture was the wrong way of privatising the state-owned companies, to the main heirs of the former enterprise 'Textile fibers', which were involved in cocoon purchasing and processing.

After the privatisation, these companies gradually stopped purchasing cocoons from farmers. At present, the absence of commercial companies, capable of purchasing and processing large quantities of fresh cocoons from farmers, appears to be the main critical limiting factor for the increase in silk production.

Feeding of silkworms using movable trays, Scientific Centre of Sericulture, Vratsa, 2012 (Source / **SES-Vratsa archive**)

Lines for labour-saving silkworm rearing at the Scientific Centre of Sericulture, Vratsa, 2012 (Source / **SES-Vratsa archive**)

Mulberry leaf powder production at the Scientific Centre of Sericulture, Vratsa, 2012 (Source / **SES-Vratsa archive**)

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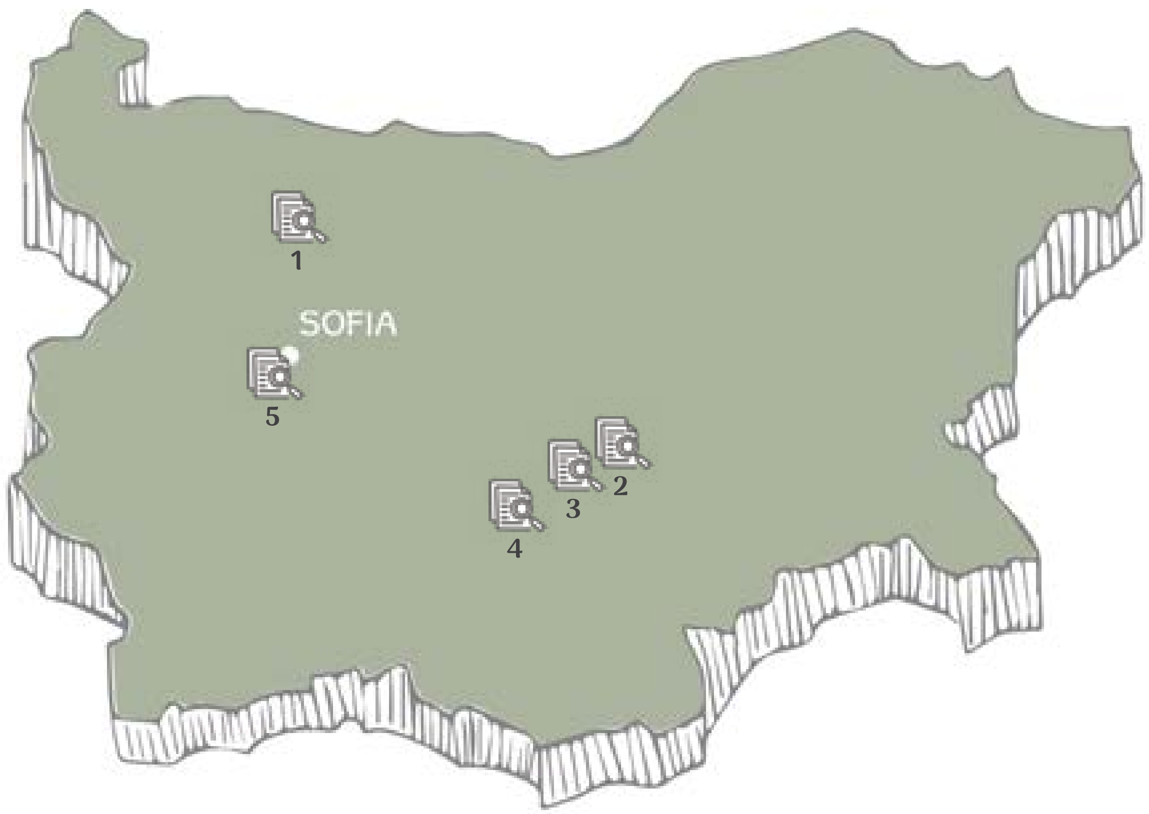

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Greece

Sericulture, silk reeling and weaving in the Byzantine Empire

In the Middle Ages, the Hellenic Peninsula was the epicentre of the Eastern Roman Empire: the most important cities and the capital itself, Constantinople, were located here. The Byzantine Empire is the name by which modern and contemporary scholars refer to the Eastern Roman Empire, of predominantly Greek culture, which was separated from the Western part, of almost exclusively Latin culture, after the death of Theodosius I in 395. Therefore, the history of Greek sericulture has its roots in the Byzantine tradition. Sericulture, defined as the agricultural activity of silkworm rearing, can be accurately identified as existing in the Byzantine Empire at the end of the 12th century. The first documented presence of the silkworm, in what is now the Greek state, comes from a passage in a letter written in 1217/1218. Before that, there were probably several attempts to introduce the silkworm to the Byzantine Empire but there is no consistent reference to successful silkworm rearing. However, Greeks were well aware of the silk origin. For example, Archbishop Photios I (810–892 AD) published a book, probably written by one of his pupils, which is called Lexicon. In that book there is an entry for the silk producing nation and silk as a textile, which is cited as follows: «Σῆρεσ: ἔθνος ἔνθα ἡ μέταξα γίνεται· ἐξ οὗ καὶ Σηρικὰ τὰ ἐκ μετάξης ὑφασμένα λέγεται.», which translates as: "Seres, the nation where silk is produced, thus serica (Σηρικά) are called the textiles made of silk". This might suggest that raw silk and, probably even textiles, were not produced in the Byzantine Empire by then, contrary to what is generally assumed. However, since the conquer of Bursa (Turkey) by the Ottoman Turks in 1326, what can be described as sericulture in Byzantine Empire appeared to be a short-lived activity apart from the probable silkworm rearing on South Eastern Peloponnese.

Silk reeling was not mentioned in the Book of Prefect, but raw silk is reported to be imported from Syria. Interestingly, reports from several historians suggest the absence of any mention to silk reeling at the time, probably because this activity was carried out by peasant women. However, silk weaving was an important and very lucrative enterprise already from the 9th century AD, as attested in the Book of the Prefect. Silk weaving was mostly for domestic consumption in the Byzantine Empire since the Cairo Geniza scripts do not describe any transaction of Byzantine silk apart from one case.

The Book of the Prefect: a testament on silk textile production in the Byzantine Empire

The Book of the Prefect is an old surviving text from the early 10th century. Its compilation and publication were overseen by the Byzantine Emperor Leo VI the Wise (886–912 AD) and it was published between 910–920 AD. It was an attempt to put the guilds that were operating in the Byzantine Empire in order and set rules and regulations for the operations and activities of each guild. It is an impressive record of the various professions that were (and still are) involved in the production of silk textiles.

In the Book of the Prefect, several guilds related to the production of silk textiles are mentioned. These are:

1) The Βεστιοπράτες (Vestioprates): Merchants of silk textiles produced in the Byzantine Empire. This guild was different from
2) the guild of Πρανδιοπράτες (Pranidioprates): who were merchants that imported silk textiles from Syria. The export of silk textiles made in the Byzantine Empire was prohibited.
3) Μεταξοπράτες (Metaxoprate): This guild consisted of merchants who bought and sold raw silk. They were not allowed to process the raw silk and were buying it from merchants who were visiting Constantinople to sell their raw silk.
4) Καταρτάριοι (Katartarioi): These merchants bought raw silk from Metaxoprates, they were processing the silk, most probably by throwing (throwsters), and they were then selling the silk threads to
5) Σηρικάριοι (Sericarioi): The merchants who were weaving silk into textiles, but it is uncertain whether they were also dyeing the textiles. They could only buy raw silk from Metaxoprates or Katartarioi, because silk weaving involves the use of both raw silk and spun silk. The role of the profession called Σηρικοπράτης (Sericoprates) describes merchants who were probably working on the finished textiles that were then sold to Vestioprates. Finally, there was another guild, that of
6) Οθονιοπράτες (Othonioprates), who were merchants exclusively of linen textiles.

The Book of the Prefect also mentions two other professions related to silk: One is called Μεταξάριοι (Metaxarioi) and the other is called Μελαθράριοι (Melathrarioi). It is unclear what the role of these professions was, but they did not belong to any guild. Most probably the Metaxarioi had the same profession as the Metaxoprates, as suggested by several historians, but did not belong to a guild, while the Melathrarioi were merchants who traded low quality raw silk. It is noteworthy, that in the Book of the Prefect there is no mention of silkworms or cocoons, only of raw silk.

SILK HISTORY

4th century BC
Aristotle (384-322 BC) in his book 'History of Animals' describes the production of silk from cocoons, at least in the island of Kos, of what is now known as Coan silk, but this silk was probably made by another lepidopteran insect called *Pachypasa otus*.

2nd century AC
Silk textiles are found in Palmyra, Syria, but this silk comes from *Antheraea mylitta*, an Indian wild silk moth.

553–554 AD
Byzantine Emperor Justinian I is introduced to a silk producing insect by monks who brought eggs from the land of Syrinda (Σηρίνδα) to Byzantium. This silkworm was probably *Bombyx mori* since the use of mulberry leaves as food is also mentioned in the narration.

870-890 AD
Archbishop Photios I (810-892 AD) reports reading the account of Theophanes about a Persian who showed to the Byzantine Emperor Justin II (565-580 AD) silkworms that he had brought from Syria (έκ Σηρῶν).

900-910 AD
Byzantine Emperor Leo VI the Wise (886-912 AD) oversees the publication of the **Book of the Prefect** where the various professions involved in silk weaving are described.

1162
Benjamin of Tudela, a Jewish Rabbi who travelled to Thebes in Greece, reports on the silk weaving industry in this town. Thebes was sacked by Roger II of Sicily in 1147 and hundreds of silk workers were transferred as slaves to Sicily, to his Norman kingdom.

1195
Byzantine Emperor Alex III is ordered to pay to Sultan Muhyi al-Din silk textiles from Thebes as war compensations.

1217/1218
Ioannis Apokaukos, an Archbishop of Nafpaktos writes in a letter of the silk-producing worms that were destroyed during a pirate raid on Nafpaktos.

1494
Pietro Casola, a Venetian who travelled to Corfu, Methone and Rhodes reports that in all these 3 places production of silk is taking place under Venetian rule at the time. In the town of Methone he reports of Jewish people working on silk weaving.

1591
Lorenzo Bernardo reports that in the town of Giannitsa (under the Ottoman rule) the silk weaving industry is thriving.

1657
Jean Thévenot visits the island of Chios and reports on the silk weaving of the people of the island, as well as the silk weaving of Andros and Tinos (all under Ottoman rule). Jean Thévenot describes in great detail the garments produced in Chios, which were then traded in Bursa and Istanbul.

1760–1770
Joseph Guichard gives detailed accounts of silk production from the island of Chios.

1830–1862
Silk reeling factories are built in the newly established Greek state in Southern Greece. 1) In 1836, the first silk reeling factory in Sparti founded by the Durutea family. 2) In1838 one silk reeling factory in Messene founded by the Durutea family. 3) In 1843, one silk reeling factory in Nafplio run by N. Loviselli. 4) In 1855, one silk reeling factory in Athens and another silk reeling factory in Patras run by Felps & Co.

1862
Pebrine disease occurs in Greece and eliminates silk production.

1869
Pebrine disease occurs in the areas of Greece that are, by then, under the rule of the Ottoman Empire and silk production is eliminated.

1880
Silk production recovers but is now mostly confined to Northern Greece (under the rule of the Ottoman Empire).

1900–1910
Silk reeling plants are established in Soufli but silk production is also well established in Edessa, Serres, Agia, Thessaloniki, Messini and Andros.

1903
The first silk reeling factory is established in Soufli by the Azaria brothers.

1909
Foundation of the 'Fratelli Ceriano' and 'I. Koukoulis and Sons' silk reeling factory in Soufli.

1911
The 'Ceriano Fratelli' and 'I. Koukoulis and Sons' silk factory in Soufli close due to the Italo-Turkish war.

1920
The Jewish merchants, Bohor and Elieser Djivre, buy the Ceriano factory, which was founded in Soufli in 1909.

1925
P. Chatzisavvas from Bursa, Turkey, opens a silk reeling factory in Soufli. At that time, Soufli is established as the main silk production centre in the Greek state.

1954
The Tsiakiris silk reeling factory is established in Soufli.

1955–1960
Silk production in Greece declines rapidly.

1963:
The Djivre factory in Soufli ceases to produce silk. SilkLine, the silk factory of the Mouhtaridis family, is established in Soufli.

2023
Silk reeling and weaving is limited to only 3 factories in Greece, all operating in Soufli.

Sericulture, silk reeling and silk weaving in the Ottoman Empire and under Venetian rule

Certain areas of Greece were under Venetian or Genoese rule well into the 17th century, and in these areas (the Ionian islands, parts of the Peloponnese and several Aegean islands and Crete) silkworm rearing was introduced by the Venetians or Genoese and flourished even until the mid-19th century.

In parts of Greece under the Ottoman rule, silkworm rearing also flourished, but there are no reports of the exchange of silkworm races between the Ottoman Empire and Venice or Genoa until the 19th century. Silk textiles were actively imported and exported between those states, as attested by descriptions of western merchants positioned in Istanbul, who traded silk textiles with partners in Western Europe.

The import and export of silkworm eggs was also very active between Italy, France and parts of the Ottoman Empire as evidenced by the occurrence of the pebrine disease in Greece and Turkey after its first occurrence in the Cevennes, France, in 1948.

A silkworm egg box from Thessaloniki dated before 1912. Note the inscriptions in Arabic text, an indication that these silkworm eggs were sold in the Ottoman Empire (Source / **S. Dedos**)

Sericulture, silk reeling and silk weaving in the established Greek state in the 19th century

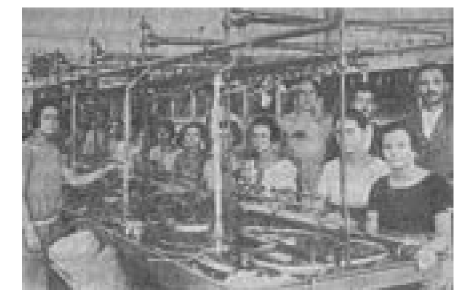
There were several silk reeling factories that were established in the mid-19th century in the newly established Greek state, which was confined to the southern parts of what is nowadays the Greek state. What is now Northern Greece was annexed by the Ottoman Empire at the beginning of the 20th century.

Silk reeling factories were also present in several areas of Northern Greece, but all of them experienced the decline of silk reeling due to the pebrine disease.

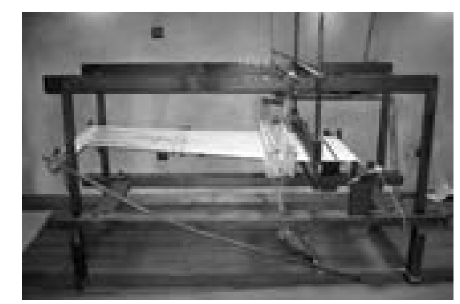
Silkworm rearing, silk reeling and silk weaving flourished in Greece after 1880 and all through the 1940s. Urbanisation, the introduction of other crops and a lack of modernisation of these activities caused a decline since the 1950s and this trend has continued despite the introduction of EU subsidies for silkworm rearing in Greece in the 1980s. EU subsidies are a lifeline now for silkworm farmers in Greece and in 2023 there were only three silk reeling and silk weaving enterprises in Greece and all three are concentrated in Soufli.

A silk reeling factory in Athens in 1928. A suburb of Athens called Mataxourgeio takes its name from the presence of such silk reeling factories in that suburb about a century ago (Source / **S. Dedos**)

Silkworm cocoon harvest. This photo dating back from the 1950s shows the traditional method of cocoon harvesting after mounting of silkworms on oak branches. It was a time of celebration with family and friends (Source / **S. Dedos**)



Silk reeling workers in the factory. Note the semi-automatic silk reeling machines used (Source / **S. Dedos**)



An old silk weaving loom. This type of looms was traditionally used by women to weave silk textiles in their homes (Source / **S. Dedos**)

The built environment of Soufli

The Azaria silk reeling factory built in Soufli, in 1903. Note the main premises of the factory on the background on the left. The building on the front was still standing until the late 1990s (Source / **S. Dedos**)

A typical 3-storey silkworm rearing house in Soufli. This building was built in 1903 (Source / **S. Dedos**)

A typical cocoon storage building in Soufli. This purpose-built structure has been renovated into an elegant hotel (Source / **S. Dedos**)

Between 1885 and 1915, the built environment of Soufli was shaped, and these influences are still visible today. Many of the houses that had areas dedicated to silkworm rearing are still intact or have undergone minor alterations to accommodate the family's needs. The buildings are distinct as structures, specifically designed to function as places for silkworm rearing and cocoon storage. They were built by local craftsmen out of wood, stone, and brick.

The older houses had a one floor with three rooms, as well as a cellar, and a stable. The cellar was used to store mulberry leaves and/or cocoons during May to June. The newer houses had two or three floors. The first floor was similar to the houses mentioned above. The second and the third floor were used for silkworm rearing and contained the beds for the silkworms. A third type of building also appeared, that of the cocoon houses, or as they were locally called *bitziklikia*. They were owned by wealthier families or cocoon merchants, and they were designed to house only silkworms and not humans. They usually had two or three floors with beds for silkworm-rearing or to dry and store cocoons. From 1870, the first industrial units began to appear, the most characteristic being the silk factory of Azaria, which later became the property of the Djivre family.

The Djivre silk reeling factory in Soufli in full operation in 1925 (Source / **S. Dedos**)

Local mulberry cultivation

The cultivation of mulberry trees in Greece traces its roots back to ancient times. The mulberry tree was first mentioned by Theophrastus, the ancient Greek philosopher and botanist (371–287 BC), who first reported the presence of mulberry in Greek history and highlighted the value of mulberry wood and the nutritional properties of its fruit in his book 'Περὶ φυτῶν ἱστορία,' (350-287 BC).

Sericultural history takes a significant turn in 553-554 AD, during the Byzantine Empire under Emperor Justinian I, when monks introduced a silk-producing insect, likely *Bombyx mori*, from Syrinda (Σηρίνδα) to Byzantium. This event, is documented for its serendipitous introduction of silk production to the region and underscored the mulberry's crucial role as a food source for the silkworm, thereby elevating the tree's agricultural and economic importance.

Until the early 14th century, mulberry is mentioned in various texts under names like Συκαμηνιά and Συκαμιά, though without clear classification into black mulberry (*M. nigra*) or white mulberry (*M. alba*). This period reflects a continued recognition of the mulberry, albeit with a lingering ambiguity about its specific varieties.

The 18th century saw a more structured approach to mulberry cultivation, particularly in the island of Chios, then under Ottoman rule. Between 1760 and 1770, Joseph Guichard provided detailed accounts of mulberry planting for leaf production on Chios. He describes specific methods of leaf harvesting from the mulberry trees, which allowed the trees to grow to massive sizes that yielded around 280 kilograms of leaves per tree.

By 1846, new mulberry varieties were pursued beyond Greek borders with Stefanus Marcella's description of six mulberry varieties in France and the assertion that the best yield was achieved when mulberries were propagated by grafting, reflecting the growing scientific and agricultural knowledge of mulberry cultivation.

In 1927 another publication on sericulture provided details on nine distinct varieties, representing a significant leap in understanding and classifying mulberry trees in Greece, from wild and semi-wild morphotypes with expressed lobation, to those with simple heart-shaped leaves best suited for silkworm rearing and fruit production. Furthermore, sycamore mulberry classified as *M. alba* var. platanifolia as well as introduced high-yielding varieties from Japan and Italy ('Cattaneo') were mentioned. The latter half of the 20th century to present day has been characterised by a dramatic increase in the diversity of introduced mulberry varieties in Greece, driven by massive imports from Italy, Japan, China, and other countries. This introduction has transformed the mulberry landscape in Greece, with varieties now serving primarily as ornamentals in landscape planning within the urban and rural environment. In regions like Evros, the cultivation of mulberries for sericulture persists, blending traditional practices with modern varieties.

MULBERRY HISTORY

350 BC
Theophrastus (371–287 BC) in his book "Περὶ φυτῶν ἱστορία" provides descriptions of the tree, informing us of the value of its wood. Throughout the centuries in Greece, mulberry was used as a medicinal plant and had many other uses by humans beyond its use as an ornamental tree.

100–1400 AD
Mulberry is described in several textbooks as Συκαμηνιά, Συκαμιά, Σκαμνιά and derivatives of such names. However, there is no clear description that the tree which is mentioned can be classified as either *Morus nigra* or *Morus alba*.

1760–1770
Joseph Guichard gives detailed accounts of mulberry planting for foliage production and how to plant mulberries for leaf harvests in the island of Chios. Chios was under the Ottoman rule by the time.

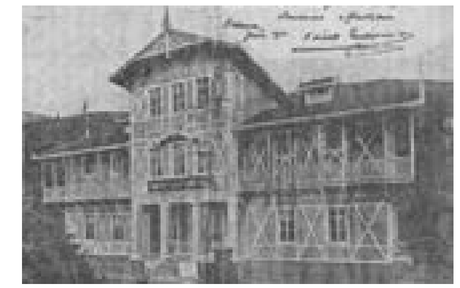
1846
Stefanus Marcella, in his textbook on sericulture, describes 6 mulberry varieties found in France. He states that the best mulberries are produced by grafting.

1927
A detailed description of mulberry varieties in Greece is provided in a textbook on silkworm rearing. In total 9 varieties are described.

1970–2023
Massive imports of mulberry trees from Italy, Japan, China and several other countries lead to a multitude of varieties currently present in Greece and used almost exclusively as ornamental trees. Only in areas where silkworms are reared, mulberry trees are actively cultivated. In the region of Evros, the local variety called Bursa or Prousa (an indication of its origin in the city of Bursa in Turkey) dominates, but modern plantations of Italian or Japanese varieties are becoming popular. In general, all trees are pruned to a high trunk height while imported varieties are sometimes pruned to a medium height of trunk in plantations.

An artistic drawing of a silkworm on a mulberry branch from an 1890 textbook on sericulture. Note the shape of the mulberry leaves in the drawing (Source / Φιλιππίδης, Σ., 1890).

Throughout this history, the mulberry tree has transcended its origins to become a fixture in Greek life, providing shade, beauty, and a link to the sericultural past. With more than a million trees across the country, the mulberry's legacy in Greece is a testament to its enduring value, from ancient wood source and sericulture cornerstone to today's ornamental and cultural landmark.



Institute of Sericulture (Harir Darut Talimi) established in Bursa in 1888 (Source / **S. Dedos**)

Entities related to Sericulture and Silk production

There can be a long list of entities related to sericulture and silk production in Greece. Some distinct ones are:

1) The Institute of Sericulture (Harir Darut Talimi) that was established in Bursa in 1888 and was closed in 2004. The building still stands in Bursa, Turkey.
2) The Djivre silk reeling factory in Soufli. A massive complex of industrial buildings that have been restored and can be visited.
3) The silkworm egg production factory of Brikas family in Soufli. An impressive and restored building that was used for silkworm egg production until the late 1950s. In Soufli and its surrounding villages there are still several silkworm rearing houses. Most of them have been converted to other uses.
4) In 1914, the Laboratory of Sericulture was established in Athens, Greece, to manage and supervise the increasing cocoon production in Greece. After the decline of sericulture in the 1960's and 1970's this institution lacked any scope of its activity and was only carrying out checks on the imported hybrid silkworm eggs for the presence of pebrine. The Laboratory of Sericulture was housed in the premises of the Agricultural University of Athens and was closed in 2011.
5) In 2022, the Vocational School for Sericulture and Silk Production was established in Soufli. This is the only vocational school in Europe devoted to sericulture and training of its students.
6) Research centres dedicated to sericulture have never existed in Greece. That said, there were prominent scientists who worked with the silkworm as an insect model, such as Prof. Fotis Kafatos, who did extensive work on the oogenesis of the silkworm. However, all his research and that of other Greek scientists was based on the silkworm as an insect model.

Cocoons from native silkworm races of Greece from 1938 (Source / **Laboratory of Apiculture and Sericulture of the Agricultural University of Athens**)

It is important to note that sericulture as a field of agricultural teaching and training was not part of the curriculum taught at any agricultural universities in Greece. It was only a brief sub-division of courses on Apiculture taught to higher education students, if at all. It is very important for the reader to understand the scope of this assertion: Since the 1950's there is no key figure or entity connected to sericulture. In the first half of the 20th century one can name the owners of the silk reeling factories in Soufli as key figures and in the 19th century one can name some businessmen, who owned and managed silk reeling plants in southern Greece, but none of these persons are well known or remembered today nationally.

The Brikas family silkworm egg producing factory in Soufli. This landmark building was in full operation until the late 1950s (Source / **S. Dedos**)

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Contacts

EDUCATIONAL INSTITUTIONS AND RESEARCH CENTERS

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2. Laboratory of Sericulture and Apiculture, Agricultural University of Athens

Iera Odos 75, Athina 118 55, Greece
http://efp.aua.gr/en/node/278

SILK CRAFT, MANUFACTURE AND SILK ART MUSEUMS

1. The Silk Museum

Eleftheriou Venizelou 73
GR-684 00 Soufli

SILK PRODUCTION COMPANIES WITH RECOVERY OF OLD TRADITIONS

1. Tsiakiris Silkhouse

http://www.silkhouse.gr/.
This is the website of the silkworm rearing, silk reeling and silk weaving company of **Mr. G. Tsiakiris** that operates in Soufli since 1954.

2. Mouhtaridis

https://silkline.gr/.
This is the website of the silk reeling and silk weaving company of **Mr. K. Mouhtaridis** that operates in Soufli since 1963. The company runs an automatic silk reeling machine since 2022. This is the only such automatic silk reeling machine in Europe.

3. MetaXana

https://www.metaxana.com/.
This is the website of a silkworm rearing, silk reeling and silk weaving company that has been established in Soufli since 2014. Headed by **Mrs. Anne Garcin** the company operates on a circular economy principle and produces silk textiles exclusively created in Soufli.

Georgia

Sericulture in the past

4th century BC
Oldest silk fiber found in the Pichvnari necropolis (Georgia).

5th century AC
First written mention of sericulture in Georgia.

1844
More than 3000 weaving looms are counted in the villages of eastern Georgia.

1850s
Opening of the first reeling plants.

1860s
2,770 tonnes of cocoons were produced annually throughout the country.

1861–72
Pebrine epidemic in Georgia.

1887
The Caucasian Sericulture Station was established in Tbilisi using the Pasteur method.

1888–1904
Annual theoretical and practical courses in sericulture and apiculture were held at the Caucasian Sericulture Station, with a total of 765 students attending.

1926
Establishment of the 'Georgian Silk' Trust operating under the Soviet Government, which established 3 silkworm egg producing stations in Kutaisi, Chokhatauri and Vani.

Sericulture has been an essential part of Georgian culture and economy since ancient times, and Georgian silk production traditions are even listed among the intangible cultural heritage of the country.

The documented history of silk production in Georgia starts from the 5th century AD when King Vakhtang Gorgasali brought back silkworm eggs from his trip to India. However, some scholars believe that Georgia may have been introduced to sericulture even earlier, as mulberry is endemic to the region and unique strains of silkworm have been found here. Additionally, silk fibres from the 4th century BC were found during excavations at the Pichvnari necropolis.

One of the routes of the Great Silk Road passed through Georgia, suggesting that silk trade also took place locally. Remarkable are the notes of the famous Italian traveller Marco Polo, who mentions that many golden textiles were woven with silk threads in Georgia. The works of Arcangelo Lamberti, Jean Chardin and other international travellers also report about sericulture in Georgia.

Weaving Daraya silk on the local loom. Photo by Konstantin Zanis, 1893, Georgia, Ozurgeti, Bakhvi (Source / **State Silk Museum**)

Upper left: The main building of the Caucasian Sericulture Station (now a museum).
Upper right: Staff residence of the Caucasian Sericulture Station.
(Photos / **K. Zanis**, 1892; Source / **State Silk Museum**)

Silk manufacturing and industrial silk production

In the 17th and 18th centuries, various crafts were related to sericulture. For example, the dyeing of 'Daraya' (one of the special types of domestic woven silk textiles, mostly used as headscarves in western Georgia) and other textiles was regarded as a separate profession.

In the 1850s, a number of reeling factories were established in Georgia by Europeans to produce high quality silk textiles. By the end of the 19th century the Caucasian Sericulture Station played an important role in the development of silk production.

In Soviet Georgia, silk production became a major industry and sericulture and moriculture were established as separate fields of research. There were silk spinning and weaving factories all over Georgia, producing industrial textiles (important samples are preserved in the Silk Museum collection) for the whole Soviet Union. In the 1960s, production was at its peak and gradually began to decline due to a number of economic and environmental factors. Since the collapse of the Soviet Union the industry has completely stopped, but scientific research, training of young scholars and conservation of Georgian silkworm strains are still active at the Sericulture Laboratory of the Agriculture University. Additionally, at the Sericulture Laboratory of the Agriculture Research Centre (in Tsilkani) Georgian silkworm breeds are studied and new ones created.

The State Silk Museum is one of the main institutions in the country preserving and disseminating silk related knowledge through its collections and activities.

1929
There were 5 silk dyeing, 1 silk spinning and 2 silk weaving factories producing 153,830 kg of raw silk and 98,896 metres of textile annually.

1930
Under the Soviet Government the Caucasian Sericulture Station was transformed into a research institute.

1936
There were 11,153,300 mulberry trees throughout the country.

1945
The first Georgian silkworm breed was created by selection.

1960s
4,500 tonnes of cocoons were produced annually throughout the country.

1963
Beginning of the sericulture decline due to mulberry dwarf leaf disease.

2002
End of silk production in Georgia.

2014
Creation of the Agriculture Research Centre and the Sericulture Laboratory, which serves as a repository for mulberry and silkworm gene pools.

2018
Georgian silk production traditions were included in the intangible cultural heritage of the country.

Soviet mulberry plantation in Dighomi, Georgia (Source / **State Silk Museum**)

Tbilisi Silk Weaving Factory in 20th century (Source / **State Silk Museum**)

The mulberry silkworm gene pool

Among the republics of the former Soviet Union, Georgian silk ranked first in terms of quality. It has always been highly exploited. Even today, there are some silkworm strains that are very interesting in terms of industrial and biotechnological applications.

Some highly productive Georgian breeds are characterised by a very high cocoon yield, i.e. a cocoon thread length over 2000 m and silk percentage of about 24-25%.

The highest quality crepe chiffon fabric is made from the thread of the Mziuri strain, which was awarded the “Platinum Star” at the International Quality Exhibition in Spain in 1998.

Since 2014, the Tsilkani Sericulture Laboratory of the Ministry of Environmental Protection and Agriculture, the Georgian Research Centre and the Sericulture Laboratory of the Agriculture University of Georgia have been working to preserve and improve the gene pool of the silkworm. Today, the gene pool today preserves ancient Georgian strains as well as 40 local and 30 foreign selected breeds. This silkworm gene pool is the only one in Georgia, and its preservation is extremely important for the revival and further development of sericulture.

Gathering mulberry leaves for silkworm feeding in the State Silk Museum, 2015 (Source / **State Silk Museum**)

Feeding silkworms in the State Silk Museum (Source / **State Silk Museum**)

Local mullberry cultivation

The black mulberry has been widespread in Georgia since the middle of the Tertiary period. There is no precise information on when the white mulberry was introduced to Georgia. The tradition of sericulture in Georgia is indeed ancient. Historical accounts suggest that it dates back to the 5th century of the reign of King Vakhtang Gorgasali, a seminal figure in Georgian history, known for founding Tbilisi, the capital of Georgia.

The white mulberry is characterised by its genotypic diversity – there are many small-leaved, endemic fruit species that are considered to be the ancestors of modern varieties and are particularly valuable for the nutritiousness of the leaf and flavour of the fruit.

Mulberry can be found all over the country, from sea level to 1600 m. It is a self-renewing fast-growing plant that easily adapts to the human cultivation and pruning and to growing conditions in different environments. It loves light, heat and humidity, but can also tolerate shade, drought and winter frosts. It grows to a height of 15–20 m and can live for up to 200 years.

Mulberry leaves were widely used for sericulture throughout the country until the plants became seriously infected by a virus. Dwarf leaf disease was first discovered in Far East Asia, but it also affected plantations in Georgia, where the disease was very well studied. The dwarf leaf disease was first detected on only few trees in 1963 at the Kutaisi Regional Sericulture Experiment Station in western Georgia. By 1968, the disease had spread to 20 provinces and infected mulberry trees throughout western Georgia, destroying more than 10 million of the total 12.7 million trees. The rapid spread of the disease was aided by the fact that the basic mulberry variety at that time, called 'Georgia' appeared to be very susceptible to the disease. The disease attacks the whole crown of the tree and is spread by the mulberry cicada Hishimonus sellatus Uhler through infected saplings or cuttings. Some of mulberry varieties are very susceptible to the disease, but others are comparatively tolerant.

In fact, scientists in Georgia were relatively quick in suggesting to adopt new mulberry varieties that were resistant to the dwarf leaf disease, allowing mulberry plantations to be restored in 1970s.

In 2003, the most popular varieties in Georgia, at the field level, were those bred in the country: Imereti 90, Saamo 91, Racha 9, Racha 10, Egrisi, Novogruzinskii 2; among the Japanese ones: Oshima, Ichinose, Kairiou Rosou, Rokoko Jaso and the Chinese Rosou. Additionally, there are local mulberry accessions in Georgia including Tbilisuri, Iveria, Kutaturi, Gruzniish-4, Hybrid-2, Imeruli-1, Imeruli-2, Guria-10, Guria-20, Kolkheti-85 and Nata, which are relatively resistant to the dwarf leaf disease.

In 2003, there were about 4 million mulberry trees in Georgia. Nearly 50% of them are of highly productive good varieties, which is a very good achievement for the country. The cultivation shape is medium to high stem (1.5-2 m height). Only about 20% of the trees have been planted as compact plantations. Most of the individual trees are situated near the fences of the farmers' yards. The average leaf yield per one single tree is about 10–12 kg.

Hanging strings of cocoons at the State Silk Museum, 2015 (Source / **State Silk Museum**)

Prospects for the future

Currently, the silk industry in Georgia is in a difficult situation, but there are some attempts to save it.

In 2016, 100,000 mulberry saplings imported from Uzbekistan by Georgian businessmen gave some incentive to the people and 4 sericulture cooperatives were established, 2 of which produced a notable amount of cocoons and spun yarn locally.

The cooperative 'Abreshumkhvevia' cooperative in Akhmeta village (headed by Nunu Nakhutsrishvili) employs the residents every year to feed the silkworms and obtain a notable amount of cocoons. A cocoon dryer and other equipment have been preserved here, as well as a dozen hectares of mulberry plantation.

A mulberry plantation was established at the Lagodekhi Nunnery to feed silkworms and employ people by weaving silk and making various silk handicrafts.

The Sighnaghi region is also important for the sericulture field. Ms. Lamara Bezhashvili, who lives there, is one of those unique masters who preserve the forgotten Georgian silk craft and teach silk production to the villagers.

The Ministry of Agriculture and the Ministry of Economy and Sustainable Development have a strategic vision for the development of the silk sector. In 2015, a research project called 'Silk House' was launched to revitalise the silk industry in Georgia.

Despite the fact that silk production has stopped in Georgia, the rich gene pool of mulberry and silkworms with highly productive and high-quality cultivars and breeds has been preserved, which is the most important basis for a future sericulture revival.

Prospects for the future

The Silk Museum was founded in 1887 and it has been housed in the main building of the former Caucasian Sericulture Station since 1891. The founder of the complex, biologist Nikolay Shavrov, developed the concept of the station based on the European model. The aim of the station was to control the health of silkworm eggs using the Pasteur method, and to promote and develop sericulture and apiculture throughout the region. The museum and library, located in the main building, with their various collections and books, played an important role in the educational activities of the station and contributed to raising public awareness in this field.

The Caucasian Sericulture Station was located in the Mushtaid Garden in Tbilisi. It consisted of 23 buildings with different functions, two of which have been preserved to this day. The whole complex, including the showcases were designed

Books from the museum library, 2013.
Photo by Guram Kapanadze
(Source / **State Silk Museum**)

by the Polish architect Aleksander Szymkiewicz and today it is listed as a cultural heritage monument in Georgia.

In the course of history, the Caucasian Sericulture Station changed its function and status several times. In 1930, it became a research institute that functioned until the 1970s. In 1981, the building was given to Dinamo Stadium, and the survival of the museum became questionable. The fight to save the museum, led by Irine Chotorlishvili in 1986–88, was successful, and the museum began to function under the leadership of the Bureau of Sericulture. In 2006, the management of the organisation was transferred from the Ministry of Agriculture to the Ministry of Culture, and the institution was given museum status.

As the museum originally had an educational function, its focus is not only on textiles, but it preserves all kinds of objects related to sericulture, including cocoons, silkworm biology, textiles, photographs, specimens related to the mulberry tree, dyes, threads, sericulture tools and equipment, etc. The museum houses up to 40,000 objects and 20,000 books from 50 different countries.

Nowadays, while maintaining its collection and authentic atmosphere, the museum is also dedicated to implementing research projects as well as educational programmes and is open to new initiatives, such as contemporary art projects, various workshops, etc. After the museum's 4-year rehabilitation project (started in 2020), there will be more opportunities for future institutional development.

Weaving on the horizontal loom in the State Silk Museum, 2015
(Source / **State Silk Museum**)

Reeling thread at the State Silk Museum, 2015
(Source / **State Silk Museum**)

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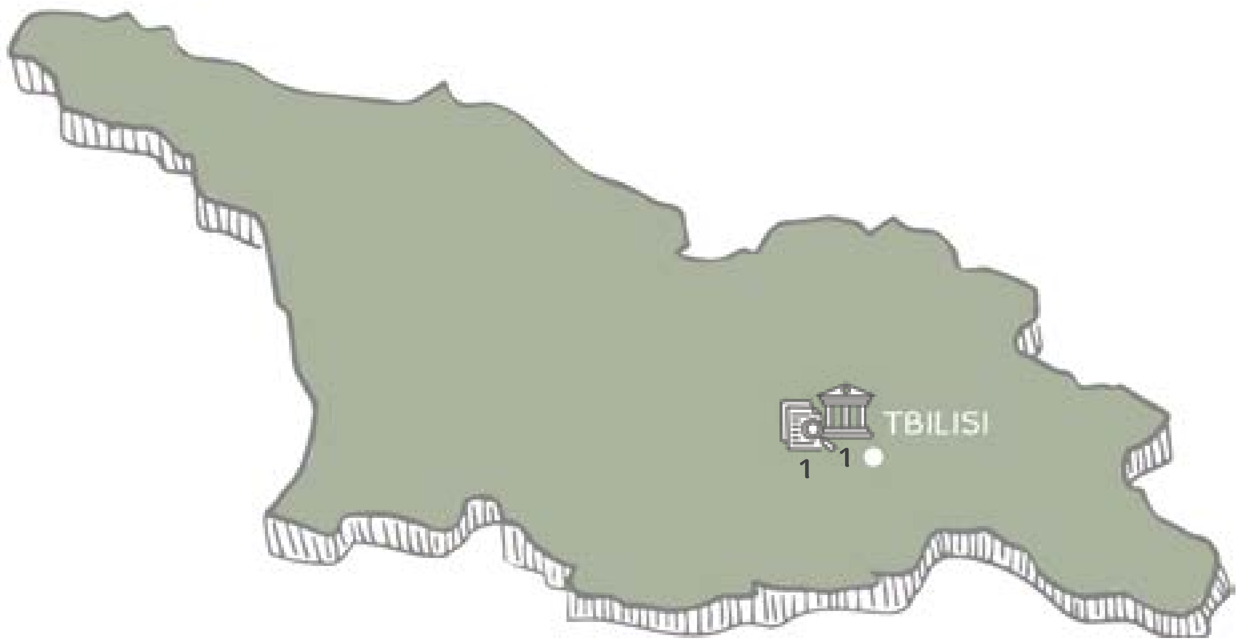

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SILK CRAFT, MANUFACTURE AND SILK ART MUSEUMS

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France

Sericulture in the past

1234
In Marseille harbour, a ship takes on board bales of silk from the Cévennes.

1296
A resident of Anduze is designated as a « trahandier » (person who pulls the silk thread) in a notarial deed.

1309
Pope Clément 5 transfers the residence of the Holy See to Avignon and planted mulberry trees around the city.

1340
A merchant from Lucca in Italy, residing in alès, hires 5 "trahandiers".

15th century
Sericulture received a significant boost from Louis XI by encouraging Italian experts to come and work in Tours' silk factory.

16th century
Silk fabric manufacture in Lyon was systematically organised by François I, at the initiative impetus of Etienne Turquet and Barthélemy Naris. At the time, France relied on Italian silk yarn imports to meet its demands due to insufficient domestic production

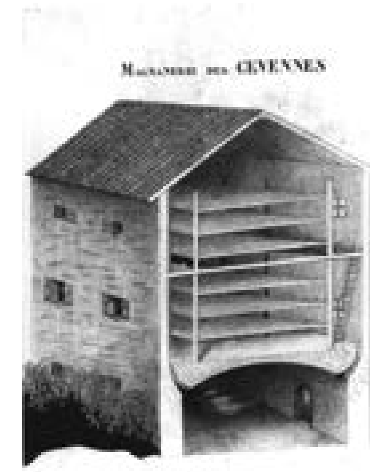
17th century
Olivier de Serres, the famous agronomist, published "La cueillette de la soie pour la nourriture des vers qui la font". From 1601, he planted 20 000 mulberry trees in the Tuileries Garden.

Before Lyon became the silk capital, several other regions in France had a history of silk production, including Montpellier, Avignon, Tours, Paris, Provence and Languedoc Roussillon. At the beginning of the 14th century, Louis XI invited Italian and Greek artisans to settle in Tours. Throughout its history, however, the silk industry in France has been associated to and revolved around the city of Lyon. Because of its geographical location and its history, the city had a great commercial importance, including the development of silk trade with Italian cities in the Middle Ages.

However, the starting point for the development of its own silk industry was marked by the edicts of King Francis I, in 1531, who granted the city of Lyon a monopoly on silk trade. From then on, the industry flourished marked by the superior quality of its fabrics. By 1550, 10% of the city's population, or 12,000 people, earned their living from silk. At the same time, the planting and cultivation of mulberry trees was greatly expanded throughout France, largely due to King Henri IV and the renowned agronomist Olivier de Serres. Over time, the silk industry became concentrated in the south of France, where two production centres were established. One was the silk industry in Lyon, which produced high quality fabrics whereas the demanded twisted silk was produced in Piedmont using advanced technology. The other silk activity hub emerged in the departments of Ardèche, Cévennes, Gard, Hérault, Isère and Var. In these areas, cocoon production was high, but reeling and twisting were not of sufficient quality for the Lyonnese industry. This lower quality silk was used in the simpler and cheaper fabrics produced in the Nîmes area. Throughout the 18th century, royal courts demand brought the industry to unprecedented heights. However, the Revolution abruptly halted the industry's activity by reducing the demand from the nobility and the Church.

From the First Empire onwards, there was a remarkable recovery driven by the government of Napoleon I. This was the time of a technological milestone that changed the industry forever, namely the introduction of the Jacquard loom in 1804. This loom made it possible to automate the weaving process, improving productivity and quality. This gave the Lyon silk reeling plants an unrivalled superiority over the other European production centres. In 1802, there were 10.000 looms in Lyon, rising to 20,000 in 1815 and 30,000 in 1830. In 1850, the cocoons' production reached 25 millions of kilos in the Cévennes and 5 millions of kilos of raw silk. This scenario was seriously disrupted by the epidemic of pebrine disease, which appeared around 1849, and led to a decline in silk production that severely affected the producing areas of southern France. The industry was able to maintain a low level of activity by using silk imported from Asia until the research of Louis Pasteur made it possible to overcome the crisis. However, the opening of the Suez Canal in 1869 allowed high-quality products from East Asia to enter the European market at very competitive prices, undermining Lyon's supremacy. The French silk industry, already in decline, maintained its economic relevance in the 20th century, although with great ups and downs due to both wars.

After the First World War, production was between 3,000 and 4,000 tonnes of cocoons, then fell to 500 tonnes at the time of Liberation. During the Second World War, there was a brief revival in the manufacture of parachutes. Finally, competition from Asia, the emergence of new textile fibres, and a change in taste towards simpler and cheaper clothing at the end of the century led to the gradual disappearance of the French and European industry. Today, sustainable silk production still exists in the Lyon area, but in very specific commercial niches such as high-end fashion, restoration of historical heritage, technological textiles and new biomaterials.



Engraving representing a silkworm farm in the Cévennes (after Pasteur)
(Source / **Clavairolle**, 2003)

Olivier de Serres planting a mulberry tree in Pradel, engraving by Mallet
(Source / **Ozil**, 1986)

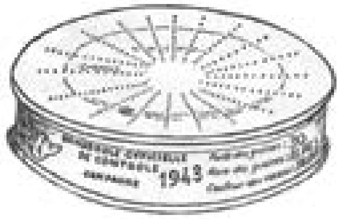
Interior of a spinning mill in Ganges (Hérault)
(Source / **Maison Rouge – Museum of the Cévennes Valleys (Saint-Jean-du-Gard)**, 1860)

Social organisation of the silk industry and sericulture and its integration into existing agricultural structures

Local silkworm strains and egg production

Reproductive cell
(Source / **Roman**, 1876)

The brood at the "nouet".
(Source / **Secretain & Schenk**, 1943)



Box of eggs
(Source / **Secretain & Schenk**, 1943)

As a result of the pebrine outbreak, sericulture producers had to buy imported eggs. Despite Pasteur's recommendations, sericulture producers continued to buy eggs from specialist producers. The egg industry, thus, replaced domestic egg production. At the end of the 19th century, French egg production and silkworm rearing specialised in different geographical areas: in the south-east with egg production plants and in the Gard and Ardèche area with silkworm rearing. Several factors explain this regional specialisation: topography, egg industry and ecological conditions. Not much is known about the traditional strains of silkworms, as many collections have been lost. However, there are three notable strains that have been multiplied for the sale of eggs and have been widely exported. These breeds are:

- **'Var' Race**: this is one of the most important strains in France, which has adapted very well to the conditions of neighbouring countries, such as Spain. The larvae are white in colour, although some have black rings with a zebra-like appearance. The larval markings are thick and bright yellow, the cocoons are yellow.
- **'French White' Race**: The larvae are white, as well as the cocoons, although the yield is slightly lower than that of the yellow races.
- **'Cévennes' Race**: The larvae are generally white and produce a pale-yellow silk of very good quality.

It is worth mentioning that in a certain period of the 19th century, attempts were made to introduce Lepidoptera species that produce so-called wild silk, such as Samia ricini, which feeds on castor beans. These species grow freely on their host plants, and do not need to be fed. However, their silk is of inferior quality and cannot be spun instead it must be carded. They have the advantage that the moth exits through the hole already prepared by the insect during spinning, eliminating the need to kill it.

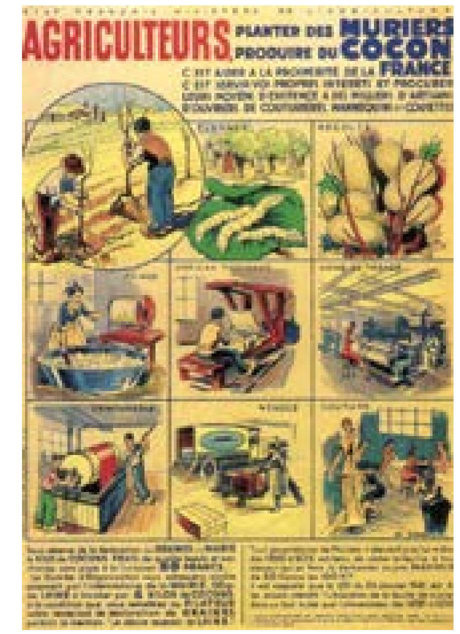
Identification of traditionally cultivated mulberry varieties

The black mulberry (*M. nigra*) was probably introduced to France during the Roman period, with the sole purpose of consuming its fruit. The earliest mention of the white mulberry (*M. alba*) in France was found in the Corsican site of Ortolo and dates to the end of the 14th century or beginning of the 15th century. In fact, although mulberry cultivation developed in the Cévennes from 1296, according to the archives of notaries in the Languedoc, it is not clear whether white mulberry had already been introduced or whether the silkworms were fed with leaves of black mulberry. In the 15th century, the white mulberry was identified in Occitania, in Carcassonne (Languedoc) and it spread because of its resistance to cold and its hardiness.

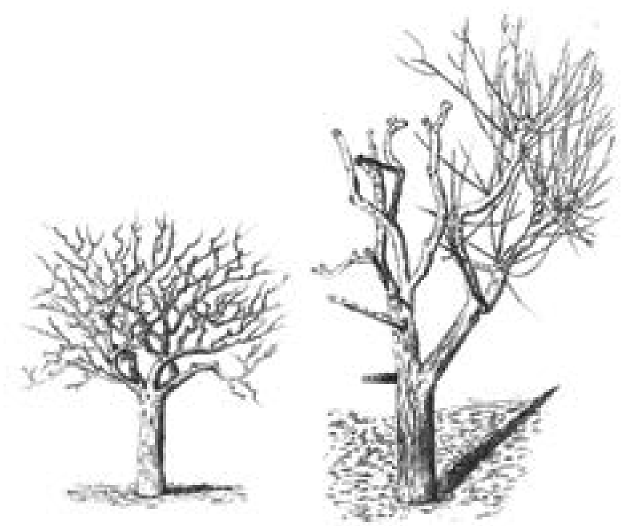
Olivier de Serres, recognized as the father of French agronomy, pioneered the method of planting mulberries during the reign of Henry IV in the 16th century. At Henry IV's behest, Olivier de Serres undertook the task of establishing large-scale silk production in France. This initiative aimed to retain the expenditures on fine fabrics within the country. Legend is said that the mulberry samplings originated from a tree brought to France during the last Crusade, which thrived notably in the south and other regions. Some mulberry trees from this aera, known as the "Sully" mulberries, still stand near Saint Hippolyte du Fort. These trees were often planted as boundary markers for plots of land, and there were strict prohibitions against cutting them down.

There is not much information about the varieties of mulberry that were planted but there were some that stood out, such as "Sauvageon", "Colombasse", "Moret-tiana", "Lhou" (of Chinese origin) and "Tartarie" mulberry. The most productive département in terms of mulberry leaf production between 1924 and 1938 was Gard, with a peak of 37,000 tonnes in 1930. In the same year, 15,000 tonnes were produced in the Ardèche and 10,000 in the Drôme.

In 1821, the Philippine mulberry (*Morus multicaulis*, according to the old mulberry taxonomy) was introduced from the Philippines to France, although it was actually native to China; this variety had the advantage of being able to grow quickly and sprout earlier. This variety was, hence, very popular for several decades. Japanese varieties such as "Kokuso 21" were also introduced in the 20th century and are still used today.



Poster presenting the procedure of sericulture, from planting mulberry trees, silkworm rearing to silk processing and marketing (Source / **Clavairolle**, 2003)



Pruning of mulberry trees: on the left, an unpruned high-stem mulberry tree; on the right, a mulberry tree being pruned (Source / **Clavairolle**, 2003)

1606
François Traucat, gardener in Nîmes, planted 4 millions mulberry trees in Provence and Languedoc. During the reign of Louis XIV, Colbert commissioned a certain Isnard to publish a memoir on the cultivation of mulberry trees and the rearing of silkworms. Colbert developped a policy for silk production. He proposed interest-free loans, subsidies, manufacturing monopolies, bonuses for the planting of mulberry trees and the free use of waterways to encourage the installation of spinning mills and silk production milling.

Research on sericulture in the history of France

1709
A harsh winter devastated chestnut and olive trees in southern France, forcing farmers to turn to a new production opportunity that was seen in sericulture. Mulberry plantations were established in the Cévennes and, to a lesser extent, in the Provence.

1760 to 1780
Cocoon production amounted to approximately 7,000 tonnes per year. Development intensified and reached a record production of 26,000 tonnes in 1853. However, this expansion came at the cost of increased silkworm diseases due to neglect of health standards.

1856
The outbreak of Pebrine disease led to a drastic reduction in cocoon production to 7,500 tonnes. In fact, this disease had already appeared in 1849, but its spread had been slowed down by the importation of Spanish and, above all, Italian eggs. In 1855, Italian egg production was also affected, and imported eggs were contaminated, resulting in a disastrous harvest in 1856.

1860s
Eggs were imported from Japan and China, but poor storage conditions in warehouses in Yokohama or Shanghai, and long-distance transport affected their quality. Imports were also made from Georgia and the Caucasus. Cocoons were also imported from Japan to maintain the activity of the reeling industry.

After the appearance of pebrine disease in the 1850s, which devastated European silk production, the solution to the problem proposed by Louis Pasteur was to select eggs from healthy moths. To this end, in all countries with a sericultural tradition, institutions were set up to promote and technologically improve silkworm rearing. In France, the Station de Recherches Séricicoles was founded in 1897 in the town of Alès (Gard). This institution operated until 1977 and was replaced in 1979 by the Unité Nationale Séricicole (UNS), in La Mulatière, near Lyon. The UNS was involved in major research projects, such as the development of transgenic silkworms for improved proteins and silk, but finally closed its doors in 2009.

However, before the creation of these state institutions, the silk industry in France had a large number of mechanics, agronomists and technicians, who continuously made ingenious technical advances that improved the industry to the point at which it became the most competitive in Europe. Some of them changed the industry forever.

This is the case for Olivier de Serres (1539-1619), an agronomist who, with royal support, studied and selected mulberries and propagated the cultivation of the mulberry tree, spreading it throughout France. On the mechanical side, Jacques Vaucanson (1709-1782), a manufacturer of mechanical devices, developed new models of spinning wheels and twisting silk fibres, allowing greater productivity and quality. In the field of weaving, Joseph-Marie Jacquard (1752-1834) deserves special mention. In 1804, building on earlier ideas, he introduced the card reader mechanism, which allowed the displacement of the warp threads to be coded for the passage of the weft, revolutionising weaving techniques. It is also worth mentioning the importance of a generation of artists and fabric designers who created new fashions based on floral designs, among whom the artist Philippe de Lasalle (1723-1804) stands out.

We must also highlight the immense contribution made by the scientist Louis Pasteur (1822-1895) to the survival of sericulture in Europe through his studies on the nature of pebrine and its prevention.

Extract cocoons in Anduze (Gard)
(Source / **B. Iglesias**, 1985)

The sericulture today

Lyon and the surrounding area are the centre of the silk industry, which employs more than 4,000 local people at numerous SMEs, including subsidiaries of prestigious luxury companies. For more than five centuries, Lyon's silk industry has been at the forefront of high-end fashion products, home furnishings and luxury textiles, and is a world leader in silk know-how and creativity.

Except for sericulture and reeling, all the main processes of the luxurious and creative silk market are performed in France or, more generally, in Europe. The Lyon silk industry is well represented in certain techniques such as silk weaving, printing and dyeing.

INTERSOIE France is the French professional association representing all companies involved in producing, using, and trading silk. Its mission is to promote and defend the French silk industry's interests worldwide. INTERSOIE France has 30 members, representing all the professions from silk yarn to silk fabric, including dyeing, printing and finishing, prestigious companies based in Lyon and a fabric of small and medium-sized industrial enterprises of this association.

Organised by INTERSOIE France, the Silk Festival in Lyon is the only annual event of its kind in Europe, bringing together the driving forces of the French silk industry: industrialists, creators, artisans, cultural and heritage players. Exhibitors are the suppliers of the most prestigious brands in the world of haute couture and high-end fashion. Since 2018, Silky Cities, the international network of silk cities and metropolises, has been led by the City of Lyon and Lyon Metropole in partnership with INTERSOIE France. In November 2019, the main silk cities of France, China, Italy, Brazil, Japan, Spain, Uzbekistan and other countries have joined the network. The network aims to create a silk ecosystem that integrates profession, culture and innovation through exchange and cooperation, and to increase the international impact of silk.

Despite the importance of the silk industry and brands in France, the agricultural process has been completely abandoned in this country. In the Cévennes, a historic silk-producing region, Séricyne has trained more than 15 farmers in silkworm rearing. The company is currently the leading actor in France in promoting the revival of sericulture.

In Monoblet, Michel Costa set up a spinning mill and planted 18 000 mulberry trees.

Soieries des Cévennes is a sewing workshop using 100% natural silk.

L'ARSOIE-CERVIN in Sumène: undisputed specialist in high quality hosiery and silk stockings whose order book is greater than production, which would require even more silkworm breeders in the region.

There is obviously the silk revival in this area!

1865
After numerous interventions, the Minister of Agriculture, Béhic, entrusted the study of silkworm diseases to Louis Pasteur, who went to Alès on 6 June 1865. In the Cévennes (Gard and Ardèche), he studied both pébrine and flacherie, leading to significant advancements in disease management and prevention.

1870
After 5 years of work, Louis Pasteur proposed a method of prophylaxis and published a book entitled Étude sur la maladie des vers à soie.

1880s
Thanks to the work of Pasteur, who recommended the use of healthy eggs, the development of pebrine was halted, but production did not increase and stabilised at between 8,000 and 10,000 tonnes of cocoons.

1891
Sericulture was the source of a picturesque and festive event. Silkworms were reared using sheets of paper perforated with small round holes. Monsieur Lué, the manager of the Casino de Paris, obtained remnants of these sheets of paper. They were used as projectiles at a masked ball held during the Paris Carnival. This was the beginning of the worldwide fashion for paper confetti, which was astonishing in its early days and still exists today.

1897
The Station de Recherches Séricicoles was founded in 1897 in the town of Alès (Gard) and contributed to sericulture research until its closure in 1977.

18th-19th centuries
Provence experienced a boast in sericulture that lasted until the First World War, with much of the silk being shipped north to Lyon. Viens and La Bastide-des-Jourdans are two of the Luberon communes that benefited most from the now extinct mulberry plantations.

2009
The closure of the Unité Nationale Séricicole marked the end of an era. The collection of INRA silkworm strains was transferred to the Sericulture Laboratory of Padua (CREA), Italy.

After the First World War
With the urbanisation in Europe, many French agricultural workers left silkworm rearing for more lucrative factory work. Raw silk was imported from Japan to fill the gap.

After the Second World War
Even after the war, silk was unable to regain many of the markets it had lost, although it remained an expensive luxury product.

1979
The Station de Recherches Séricicoles was replaced by the Unité Nationale Séricicole (UNS), in La Mulatière, near Lyon.

Cocoon deflossing (Source / **Clavairolle et al.**, 1993)

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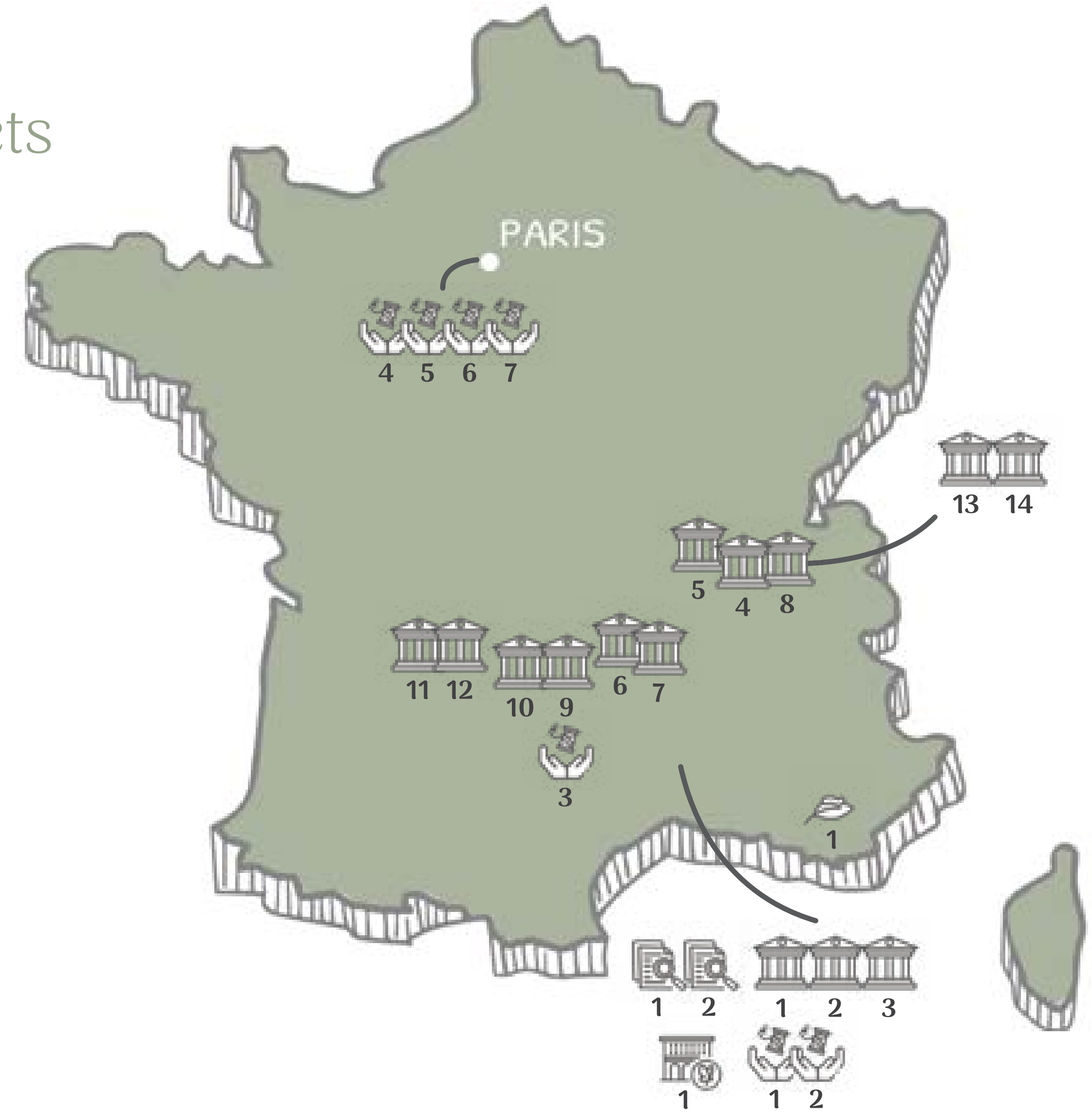
Séricyne: Fabricant de soie non-tissée naturelle, première entreprise à réintroduire la sériciculture en France.

Contacts



EDUCATIONAL INSTITUTIONS AND RESEARCH CENTERS

1. Office de tourisme Piémont Cévenol

Sauve 26, rue des boisseliers, 30610 Sauve, France
T 04 66 77 57 61
https://www.piemont-cevenol-tourisme.com/, https://destination.cevennes-parcnational.fr/trek/73288-Cros,-le-sentier-de-la-soie

2. Maison du tourisme et du Parc national

Florac Place de l'ancienne gare, N106, 48400 Florac-trois-rivières, France
T 04 66 45 01 14
E antonio.dileo@arsac.calabria.it
https://www.cevennes-gorges-du-tarn.com https://destination.cevennes-parcnational.fr/trek/74739-Magnanerie-de-La-Roque, France

SILK CRAFT, MANUFACTURE AND SILK ART MUSEUMS

1. Musée de la Soie
Place du 8 mai 1945, 30170 Saint Hippolyte du Fort, France
T 04 30 67 26 94
https://www.museedelasoie-cevennes.com/index.html

2. Maison Rouge
Musée des vallées cévenoles, 5 rue de l'industrie, 30270 Saint-Jean-du-Gard, France
T 04 66 85 10 48
www.maisonrouge-musee.fr

3. Musée Cévenol
1 Rue des Calquières, 30120 Le Vigan, France
T 04 67 81 06 86
https://musee-cevenol.fr/

4. Musée Soieries Brochier
18 quai Jules Courmont, 69002 Lyon, France
T 04 81 13 25 51
https://www.brochiersoieries.com/

5. Musées de Charlieu
9 Bd, Général Leclerc, 42190 Charlieu, France
T 04 77 60 28 84
https://musees-de-charlieu.webnode.fr/l

6. Écomusée du Moulinage
Chirols, 2 place du Bosquet in Meyras France
T 04 75 36 46 26
https://www.ardechedessourcesetvolcans.com/

7. Écomusée de la Soie
Labastide-de-Virac Château des Roures 07150 Labastide-de-Virac, France
T 04 75 38 61 13
E museobaco@terrafertile.org
https://www.chateaudesroure.com/

8. Musée des Tissus
Textile Arts Museum 34, rue de la Charité 69002 Lyon, France
T 04 78 38 42 00
www.museedestissus.fr

9. Verasoie Musée Magnanerie
320 rue de la traverse, 07150 Lagorce, France
T 04 75 88 01 27
https://lagorceardeche.com/musee-magnanerie/

10. Mas Daudet
710, Chemin de la Vignasse, 07120 ST Alban-Auriolles France
T 04 75 39 65 07
https://www.masdaudet.com/infos_pratiques.html

11. La Filature du Moulinet
Route de Valgorge, 07110 Largentière, France
T 04 75 39 26 87
http://aumoulinet.chez.com/musee/index.htm

12. Atelier Musée de la Soie
Place du 11 novembre, 26770 Taulignan, France
T 04 75 53 12 96
https://www.musee-soie.com/

13. Association Soierie Vivante
21 rue Richan 69004 Lyon, France
T 04 78 27 17 13
http://www.soierie-vivante.asso.fr/

14. La Maison des Canuts
10 et 12 rue d'Ivry – 69004 Lyon, France
T 04 78 28 62 04
E must@fondazioneratti.org
https://maisondescanuts.fr/

EX-REELING PLANTS

1. Conservatoire botanique national méditerranéen (CBNM)
34 avenue Gambetta, 83400 Hyères, France
T 04 94 16 61 40
http://www.cbnmed.fr/src/prez.php

HISTORICAL BUILDINGS RELATED TO SILK

1. Parc National des Cévennes
6 bis, place du Palais, 48400 Florac Trois Rivières France
T 04 66 49 53 00
https://cevennes-parcnational.fr/fr

SILK PRODUCTION COMPANIES WITH RECOVERY OF OLD TRADITIONS

1. Soieries des Cévennes
Filature de Grefeuille, 30170 Monoblet, France.
T 06 01 35 01 10
https://www.soieries-des-cevennes.com/

2. L'Arsoie Cervin
Route de Saint Roman, 30440 Sumène, France
T 04 67 81 30 12
https://www.cervin-store.com/fr/

3. Lamadeleine
Le mas de riols, 34260 La Tour sur Orb, France
T 0631431708
http://www.lamadelaine.fr/tag/ou%20suis-je%20%3F/

4. Sericyne & Manufacture Sericyne
Seriycne: Sericyne Paris Offices – Station F, 55 boulevard Vincent Auriol, 75013 Paris, France
Manufacture Sericyne: Filature de Gréfeuille, 04 66 78 88 04
https://www.sericyne.fr/

5. Prelle
5 place des Victoires, 75001 Paris, France
T 01 42 36 67 21
https://www.prelle.fr/fr

6. Lelièvre
13 Rue du Mail, 75002 Paris, France
T 01 43 16 88 00
https://lelievreparis.com/
https://www.tessituralacolombina.com/

7. Hermès
Paris
T 01 40 17 47 17
https://www.hermes.com/fr/fr/

Spain

The silk in Spain: origins, rise and first crisis

711
Arab tribes invade the Iberian Peninsula.

756
Creation of the Omeya Emirate with Abd al-Rahman I. Syrian tribes introduce sericulture and silk manufacture to al-Andalus.

929
Beginning of the Omeya Califate with Abd al-Rahman III. Many references of this period document the splendour of the Tiraz of Córdoba, the royal workshop for the manufacture of silk fabrics for the court.

1013
End of the Califate and start of a period of decadence of sericulture and silk fabrics. Only Granada retains its prestige.

1240
First documented evidence of silk production activity in Valencia, already under Christian control.

1285
First documented evidence of silk manufacture in Murcia, under Christian rule.

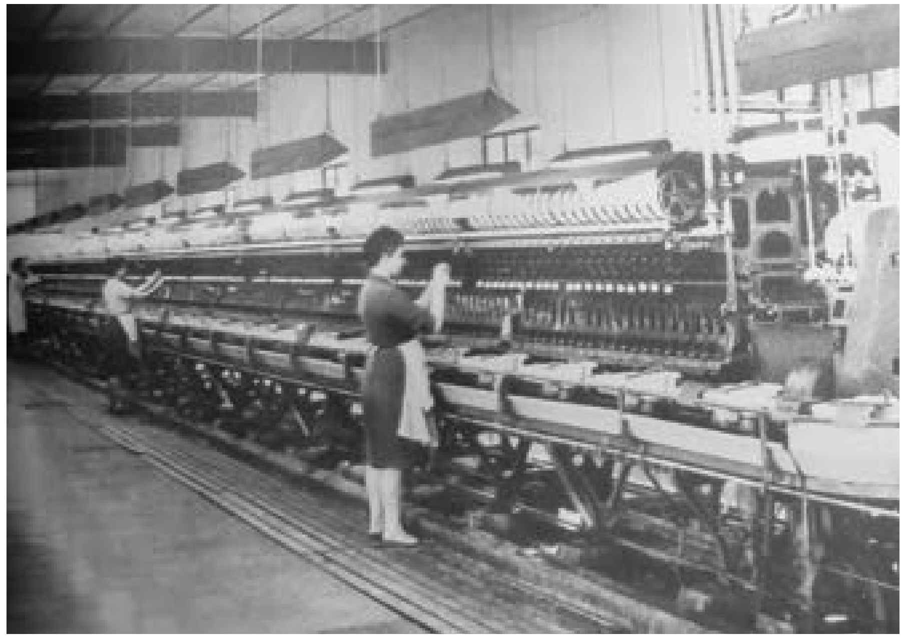
1457
Arrival and integration of Genoese artisans in Valencia, who provide the technique of velvet, starting a period of great prosperity.

The beginning of silk production in Spain is linked to the Arab conquest of the Iberian Peninsula, which began in 711 AD. From the knowledge developed in the Byzantine and Sassanid empires, the Syrian tribes who later settled in Spain (then called Al Andalus at the time) learned the techniques necessary for rearing silkworms and weaving. Although the exact date is uncertain, it is known that in the time of Ab al-Rahman II, in the middle of the 9th century, the institution of the *Tiraz* already existed in Cordoba. This was a workshop for the manufacture of luxurious silk textiles to supply the court and was supported by the sovereign. In the 10th century, the high quality of the fabrics produced in Al-Andalus was well known abroad, and Italian sources praised the quality of the fabrics known as *spaniscum*. From Cordoba, other centres of activity developed in the south, such as Granada, Almería, Malaga, and Seville.

Around the 13th century, the first records of silk activity appear in Valencia, and Murcia, which had already been conquered by the Christian kings. After the Christian conquest of Granada in 1492, which put an end to the last Muslim kingdom in the peninsula, the silk industry began to expand and flourish, concentrated in Granada, Murcia, and Valencia, reaching its peak in the 16th century. Granada and Murcia were major producers and exporters of raw and spun silk to other manufacturing centres in Spain, such as Córdoba, Seville, and Toledo. Valencia, in addition to this production, received technological innovations from a large immigration of Genoese artisans and developed a powerful industry of velvet and high-quality fabrics. The city was also a distribution centre for raw silk to other European cities.

The 17th century was a period of deep crisis. This was partly due to the general economic crisis in the country, but also to problems specific to the industry. These included an excessive tax burden and the negative effects of an incoherent trade policy. These problems were gradually resolved during the 18th century, the great century of silk in Spain. By the middle of the century, Valencia could boast an industry with more than 5,000 looms, employing half of the city's population. At the same time, it produced between 500 and 1,000 tonnes of raw silk a year, more than half the total production of Spain. Murcia was unable to consolidate its textile industry, as the interest of the dominant landowners was to produce and export raw and spun silk. As a result, up to 350,000 mulberry trees were planted in the region during this period. By the end of the century, however, Valencia was suffering from fierce competition from the silk factories of Lyon, where the industry was rapidly adapting to fashion trends and the new taste of consumers for cheaper and lighter cloths produced with the latest technology.

At the same time, the rigidity of the guild structure made innovation difficult. This difficult period culminated in the War of Spanish Independence (1808–1812), a catastrophic event that interrupted the development of a modern textile industry in Spain. It took several decades to recover, but in the middle of the 19th century, a new silkworm disease, pebrine (*N. bombycis*), appeared throughout Europe. This disease had a devastating effect on all European sericulture and marked a turning point, ruining production in almost all of Spain, with the sole exception of Murcia. Just before the appearance of pebrine, the total production of cocoons in Spain was 12,400 tonnes, with Valencia being the main producer (6,000 tonnes), followed by Andalusía (4,000 tonnes), and Murcia (2,000 tonnes). Cataluña produced only 50 tonnes but it was an exception in Spain. With a small production of raw silk, its manufactures could not compete with Valencia in the 18th century. But while that city suffered a commercial decline at the end of the century, the textile industry in Cataluña began a process of development that made it the regional leader in textiles in the 19th and 20th centuries. Some of the silk manufacturers switched to the use of cotton, and the remaining silk manufacturers developed a factory system, with salaried workers employed in plants with a superior technology, which finally moved from silk to artificial fibers in the 20th century.



Modern equipment for reeling silk cocoons into yarn in a factory in Murcia, 1970
(Source / F. C. González)

1492
Conquest of Granada by the Catholic Monarchs and end of the last Muslim kingdom in Spain. The Christians protect the Moorish sericulture and manufacture, with raw silk and fabrics exported to the rest of Spain and Europe.

1568
Rebellion of the Moors of Granada and subsequent expulsion, which leads to the decadence of silk production in Granada.

17th century
General decadence of sericulture and silk manufacture in Spain, in the context of a general economic crisis.

18th century
Recovery of the silk industry in Murcia and Valencia, which reaches historic levels of prosperity.

1808
Beginning of the of the Spanish War of Independence (1808–1812) against the invasion of Napoleon's army. The war causes great losses in most of the Spanish textile industry.

1850s
The pebrine epidemic (Nosema bombycis) destroys sericulture in most of Spain, with the exception of Murcia.

1892
Creation of the Sericulture Station of Murcia, modelled on the Stazione Bacologica of Padua.

The silk industry after the 1850s

Farmers being instructed in the observation of silkworm diseases by Sericulture Station of Murcia technicians, 1930s (Source / IMIDA)

Traditional method of silkworm rearing in Murcia, in platforms covered with a cloth in the open air and brought inside the house at night, 1930 (Source / IMIDA)

The solution to the pebrine disease came when Louis Pasteur identified the causative agent of the disease and proposed a system to ensure the health of the eggs, based on the microscopic observation of the female moths. This made it necessary to raise the technological level of silkworm rearing and led to the creation of silkworm research institutes in all silkworm producing countries, providing advanced knowledge of the biology and management of the insects. As a result, the *Estación Sericícola de Murcia* (Sericulture Station of Murcia) was created in 1892, the first and only institute in Spain dedicated to the promotion and development of the silk industry. From then on, practically all of Spain's silk was produced in Murcia, based on an agricultural structure of small farms that reared silkworms as a familiar and complementary activity to the main production of vegetables and cereals.

The productivity of this traditional structure was guaranteed by the improved technological level, as new silkworm breeds, new rearing methods, and better management of commercialisation were provided by the work of the Station. The production of cocoons in Spain increased to a peak of 1,170 tonnes in 1925, with Murcia being the main producer (953 tonnes), followed by Valencia (150 tonnes) and Castile (25 tonnes). However, during the Spanish Civil War (1936-1939) this activity suffered an almost total collapse falling to a minimum of 100 tonnes. In the post-war period, silk production was supported by the government and a recovery of the activity was observed, but in the 1970s the competition from cheaper Asian silk could not be overcome and in 1976, after the withdrawal of the subsidies that maintained a minimum of production, the activity ceased completely.

At present, there is no raw silk produced for the textile industry in Spain. Some textile silk production still takes place in Valencia, using silk imported from abroad. The Sericulture Station of Murcia was restructured in 2002 as a regional research centre for the agriculture and food industry, the IMIDA. However, after intensive research since 2000, silk fibroin proved to be an excellent biomaterial for regenerative medicine and tissue engineering. The IMIDA regained its old interest in silk and in 2005 started a line of research in this field, which is still active and successful and has stimulated the use of silk fibroin for this application in other research centres in Spain.

Mulberry varieties and silkworm races

The beginnings of sericulture during the Arab rule were carried out by feeding the silkworms with mulberry leaves of the *moral* or black mulberry, *M. nigra*. The progressive spread of sericulture to the rest of the country led to the cultivation of this species. In the 16th century, however, the white mulberry, *M. alba*, began to be cultivated in Valencia and Murcia. It has more tender and palatable leaves for the silkworms, is more nutritious and tolerates pruning better. As a result, it produces better quality silk. The hard-leaved *M. nigra*, on the other hand, is a very resistant species well adapted to the altitude and aridity of the mountainous region of Las Alpujarras in Granada, where it was grown. This led to a conflict, as the silk producers of the Alpujarras region, of Moorish origin (Muslims who converted to Christianity after the conquest of Granada in 1492), clung to the cultivation of the *moral*, which they considered to be of superior quality. The Christian authorities also defended the use of moral against the mulberry, issuing decrees banning it and ordering its uprooting. This led to the so-called 'mulberry conflict', which lasted throughout the century. In reality, however, this conflict over the quality of the silk was a measure to protect Granada silk from competition from cheaper, higher quality silk from Murcia and Valencia. Eventually, the cultivation of *M. alba* was imposed and *M. nigra* became a marginalised species that, is rarely found and cultivated only on the island of La Palma in the Canary Islands.

We do not know exactly which varieties of mulberry were cultivated in the distant past. Over time, however, two basic types of mulberry trees have been selected and considered as native to Spain. One is the '*Valenciana*' type, predominant in Valencia, which is not a single genotype but represents a group of related genotypes with different characteristics ("Valenciana" curly, "Valenciana" early). Another type that predominates in Murcia is the "Cristiana", very palatable and adapted to semi-arid conditions. After the establishment of the Sericulture Station, these two types and their hybrids spread all over Spain, as one of its tasks was to maintain mulberry nurseries and distribute free saplings to all the farmers who requested them. For decades, 20,000 saplings a year were distributed.

As for the silkworm breeds used in the past, as the only indigenous one is the race '*Sierra Morena*', a yellow silk strain, traditionally found in the south of the country. However, almost all the old breeds were gradually replaced by the new Japanese high-yield polyhybrid strains, which were introduced and promoted by the Sericulture Station in the middle of the 20th century.

1925
Peak of cocoon production in Spain in the post-pebrine period: 1,170 tonnes.

1936
Beginning of the Spanish Civil War (1936-1939), provoking the ruin of the sericulture: decline to less than 100 tons of cocoon in the period.

1976
After a moderate recovery in raw silk production in the post-war period, the activity finally collapses, due to the withdrawal of the subsidies, unable to compete with cheaper silk from Asia.

2002
IMIDA (Murcia Institute for Agricultural and Environmental Research and Development) is created, using the facilities and infrastructure of the former Sericulture Station.

2005
IMIDA starts a new line of research into the applications of silk fibroin in regenerative medicine and tissue engineering, which is still active today.

The role of sericulture in agricultural structures

Current aerial view of the IMIDA, showing the old buildings of the Sericulture Station, 2024 (Source / **IMIDA**)

View of the building of the *'Colegio del Arte Mayor de la Seda'*, (College of High Silk Art) headquarters of the guild of *Velluters* (artisans of the velvet) and now the seat of the Silk Museum of Valencia, 2024 (Source / **A. Pagán**)

The predominant method of silkworm rearing was integrated into an agricultural system of smallholders or tenant farmers working on very small plots of vegetable or cereal crops. Mulberry trees were planted on the edges of the plots or along the irrigation ditches to provide leaves for rearing, which was carried out by the whole family in the spring. In Valencia and Murcia, this was the case in the systems known as Huerta, which were very fertile plains irrigated by the rivers Jucar and Segura respectively, with a hydraulic system that was very well developed by the Muslim population. A second method, more common in Murcia, was to plant mulberry trees in large mulberry groves owned by the nobility or the Church, who sold the leaves to the farmers. Alternatively, the owners of the mulberry groves ('lords of the leaf') could provide a home for a cultivator and his family and supply him with the silkworm eggs, tools, and leaves in exchange for two-thirds of the harvest for the landlord.

Institutions, research centres and museums connected with sericulture

The most important research institution related to silk activity in Spain was the Sericulture Station of Murcia, located in the town of La Alberca, which was very active in all aspects of the silk industry in Spain from 1892 to 1976. After 1976, the Station was transformed into an autonomous regional agricultural research centre, the IMIDA, which since 2005 has successfully developed a line of work on the development of silk biomaterials, ensuring the continuity of silk research in Murcia. Another important research institution in the scientific field is the Department of Materials Science of the Universidad Politécnica of Madrid, which makes important contributions to the study of silk as a biomaterial.

In terms of cultural institutions, there are two silk museums in Spain. The Museo de la Seda (Silk Museum) of Valencia, inaugurated in 2017, is located in the restored 15th-century premises, of the former Colegio del Arte Mayor de la Seda de Valencia (College of High Silk Art). These were the headquarters of the city's silk guilds, founded in 1479 by the artisans of velvet and still active today. There is another museum, the *Museo de las Hilanderas* (Spinners Museum), in the town of El Paso, on the island of La Palma (Canary Islands), where the tradition of silkworm rearing and weaving is still alive. Another relevant museum is the *Centre de Documentació i Museu Tèxtil* (Documentation Centre and Textile Museum) in the town of Tarrasa (Barcelona), which is not a dedicated silk museum but has a very rich collection of silk garments.

View of the *'Casa de la Seda'* (Silk House) in Barcelona, the seat of the guild of veil makersfrom 1763 (Source / **Silk House of Barcelona**)

An important building in the memory of silk in Spain is the *Lonja de la Seda* (Silk Market) in Valencia, a 15th century Gothic building, and UNESCO World Heritage Site, where all the silk contracts and trade in the city took place.

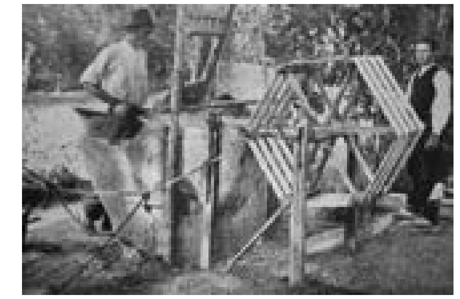
Barcelona also has a historic building, *La Casa de la Seda* (The Silk House), built in 1763 and the seat of the Guild of Silk Veil Manufacturers of silk veils (founded in 1553).

View of the *Museo de Las Hilanderas* (Spinners Museum) de El Paso, Isla de la Palma, Canary Islands, 2023 (Source / **J. L. Cenis**)

Traces of the culture and practices of rural silkworm ethnography

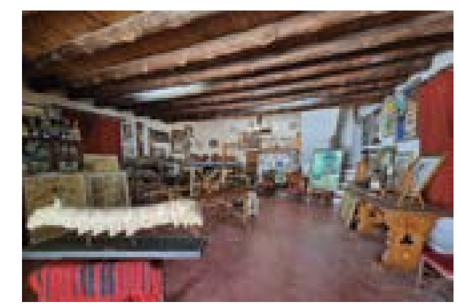
With the disappearance of sericulture from 1850 onwards in most of Spain, due to the pebrine, and the modern abandonment of the rural world, the culture, traditions, and customs associated with the silkworm and mulberry have been lost and faded from the people' memories. It is only in Murcia, where sericulture continued until 1976, that we can find manifestations of popular culture related to silk. At present, there is a small civic association called the *Peña Huertana de la Seda* (Silk Cultural Association) which preserves the traditions of old peasant culture concerning sericulture. The association preserves music, dances, clothing, and a small museum of sericulture utensils. On the first Sunday in March, following a tradition started in the 19th century, the members of the association celebrate a procession called *La Bendición de la Semilla* (The Blessing of the Eggs) in which the silkworm rearers go to a church to receive the blessing of the silkworm eggs to assure a good harvest.

There are also traces of the deep religious devotion of past silk workers. In Murcia, sericulture is under the patronage of San Felix de Cantalicio. Also in Murcia, in 1600, the guild of twisters and weavers founded the *Cofradía del Perdón* (Brotherhood of Pardon), a religious fraternity that takes part in the traditional procession held in Spanish cities and villages during the Holy Week. In Valencia, there is also worth mentioned the *Cofradía del Art de Velluters* (Brotherhood of the Art of Velvet), under the patronage of San Jerónimo and founded in 1477 by the artisans of the velvet.



A farmer with a spinning wheel to obtain silk fibre from silkworm cocoons in Murcia, 1930s (Source / **F. C. González**)

The procession of the association *"Peña de la Seda"* during which rearers from Murcia go to the sanctuary of Santa Catalina to get the silkworm eggs blessed, with a traditional stop at IMIDA, 2024 (Source / **M. Sánchez Alcaraz**)



View of the silk museum of the Association *"Peña de la Seda"* from Murcia, 2024 (Source / **M. Sánchez Alcaraz**)

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SILK PRODUCTION COMPANIES WITH RECOVERY OF OLD TRADITIONS

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Slovenia

Sericulture in the past

16th century
Sericulture spreads from Venice and Friuli to the Slovenian regions.

1724
Foundation of the Royal Filature in Farra d'Isonzo.

1725
Start of silk production in Ljubljana.

1843
Foundation of the Styrian Sericulture Society.

1844
End of sericulture in Carniola.

1869
Foundation of the k. u. k. Research Institute for Sericulture in Gorizia/Gorica.

1875–1930s
Decline of sericulture in Gorizia/Gorica, Gradisca/Gradiška and the Vipava Valley.

1948
Foundation of the Sericulture Station at Rafut near Gorizia/Gorica to revitalise silkworm. rearing in the Littoral.

1960s
Decline of sericulture and silk production in Slovenia.

Sericulture was introduced to Slovenian territory in the 16th century. Historians assume that it spread to the then Austrian territory with the emigration of people from Venice and Friuli, with whom the regions maintained close economic and cultural contacts. The spread of sericulture was very successful in the upper Vipava Valley (in Carniola at that time) and around the cities of Gorizia/Gorica and Trieste, but less successful in other parts of Carniola, Styria and Carinthia. The most important promoter of sericulture in Vipava was Ivan Jakob Fanzoi. He managed to obtain financial support from the regional government of Carniola and succeeded in purchasing silk cocoons and reeling, which enabled him to produce more than 283 kilogrammes of raw silk.

Silk production in Upper Carniola (Gorenjska) is documented from 1768, with Ljubljana and its surroundings being the centre of production. Lower Carniola (Dolenjska) was less successful in the Theresian era (1740–1780) and did not achieve any major breakthroughs in sericulture. However, the peak of production is documented in the Karst area, the hinterland of Trieste, especially in Duino/Devin and Sistiana/Sesljan, where the peasant population was predominantly Slovenian.

In the 1760s and 1770s, sericulture became a permanent occupation of the peasant population in Gradisca/Gradiška, Gorizia/Gorica, the Vipava Valley and the Karst. When the prices for silk cocoons and raw silk were higher in Venice, they were smuggled from the Goriška/Gorizia region to the local markets. The main problem for the population was to survive the cyclical crises, to feed themselves from what the land provided and to earn money for taxes. The taxes were paid with the income from sericulture revenues, and Maria Theresa (Queen of Bohemia, Queen of Hungary and Croatia, Archduchess of Austria, who ruled the Habsburg dominions between 1740-1780, as sovereign), awarded prizes and shrines to the most diligent sericulture farmers. When the patent for the promotion of sericulture was granted in the Austrian monarchy in 1763, the government set the Gradiško-Goriška/Gorizia-Gradisca region as a model for other regions, in which "serfs receive most of the funds for the payment of taxes from sericulture and silk manufacturing".

The Napoleonic Wars (1803–1815) were followed by an agricultural crisis triggered by the fall in the prices of grain, livestock and wine, which led to a renewed interest in sericulture. It was also very profitable for Austria, to which Lombardy and Veneto belonged. The revival of sericulture was favoured by a sudden rise in the price of raw silk in the years between 1820 and 1840. The agricultural societies and respected members of the industry or intellectuals played an important role, including Janez Hradecky, Jožef Orel, Janez Zalokar and Franz Hlubek. They endeavoured to make knowledge of sericulture accessible to a wider public by providing translations or publishing their own books on the subject. The newspaper Kmetijske in rokodelske novice (Agricultural and handicraft news), edited by Janez Bleiweiss, a respected member of the Sericulture Society, offered insights and updates on sericulture. In Carniola, Carinthia and Styria the agricultural societies were responsible for sericulture extension service and integrated sericulture into the regional agrultural development plan.

The Imperial and Royal Research Institute for Sericulture in Gorizia, founded in 1869, played an important role in the sericulture development. Its director, Ivan Bolle (1850–1924), focused on the research and production of healthy and disease-resistant silkworm eggs, which were distributed among the local silkworm rearers, and wrote several publications on sericulture and moriculture.

The decline of sericulture came with the extensive spread of pébrine (*Nosema bombycis*) in Slovenian areas, which decimated sericulture first in Gorizia and Vipava and later in Carniola, Carinthia and other parts.

Many wild silk moths (*Antharea yamamai*, *Samia attacus cecropia*, *Samia cynthia*) were introduced as part of the attempts to revive the industry, but none of them were as economically profitable as the domesticated silk moth (*B. mori*). In this field, Ivan Mach, with his attempt to study and exploit wild tussah silk. and Wilhelm von Ritter from Gorizia, with his experiments with Eri silk, are worthy of mention.

Although there were attempts to revive sericulture to the pre-epidemic level, ist decline became more and more evident. In 1844, Carniola decided to abandon sericulture and silk production.

Further reasons for the subsequent decline of sericulture were late-frost diebacks and fungal and bacterial epidemics of mulberry trees. Moreover, there was a poor connection between rearers and silk manufacturers. The most critical historical events in the decline of the silk industry were the Napoleonic wars, and later the stock market collapse. At the end of the 19th century, the state ceased subsidising and distributing mulberries finding better prospects in fruit production. The third attempt to revitalise sericulture took place in the last years of the First World War. The main reasons for this were the lack of raw materials and the need for supplementary activities for war veterans, widows, and orphans. During the Second World War, there was a great need for silk to produce parachutes. On this occasion, primary schools were motivated to carry out rearing with the help of children.

Despite all these measures, no significant results were achieved, and the sericulture declined until the beginning of the 20th century. This was also influenced by the introduction of synthetic fibres.

Collection centre for silkworm cocoons. Women are packing cocoons into sacks for onward transport to the reeling station (Source / I. Bolle, 1913)

2015
First attempts to revitalise moriculture and sericulture by a joint Hungarian-Slovenian research project [Influence of feeding silkmoth (*B. mori* L.) hybrid larvae with leaves of old local Hungarian and Slovenian mulberry (*M. alba* L.) genotypes on the development and health status of larvae, ARIS, NKFIH, 2016-2018] aimed in inventorying the remaining genetic resources of historical mulberries in Slovenia and Hungary, establishing collections and identifying important metabolites in leaves to test their importance for the development and health of silkworms.

2018-present
Various exhibitions, events, workshops and publications have been presented the newly acquired knowledge about sericulture and silk production in Slovenia.

Silk manufacturing and industrial silk production

Postcard with a reeling station (filature) from Fara (sent 1904) (Source / **Pillon, Come si lavorava la seta**, 1994).

Cap made of white cotton tulle, with embroidered strips of white machine lace and silk, from the vicinity of Ptuj, 19th century (Source / **Slovenian Ethnographic Museum**, https://www.etno-muzej.si/)

The most important historical period for sericulture and silk production in the region was the 18th century. The first manufacturers of silk fabrics were Filip Balestri and Jožef Pertot in 1719 in the Goriška/ Gorizia region with a predominantly Friulian, Slovenian and Italian population. Emperor Charles VI then issued an important decree, that formed the basis for the foundation of the reeling station (filature) in Fara d'Isonzo in 1724.

Silk manufacturers came to Ljubljana as early as 1725. The most famous of them was the French-born wigmaker and weaver Pierre Toussaint Tabouret (1670/1700–1747) from Nancy. He opened a manufactory for silk stockings and created the monopoly in Carniola. His workshop had three or five looms for weaving stockings, and he planted a mulberry plantation on the castle hill in Ljubljana. However, his work was not supported by the citizens of Ljubljana, so he soon closed the manufactory. He was followed by many other producers of silk fabrics and clothing: Jernej Čebul and Ludvik Anton Reja.

The manufactory which was founded in 1731 was more successful than Tabouret's; Jurij Zanetti and Jožef Harman (manufactory founded in 1754); Andrej Cerar (manufactory founded in 1775); Karl Bonomi (manufactory founded in 1788); and Jožef Kopfmüller (manufactory founded in 1792). Another silk weaving mill was located in Maribor under the master Josip Goetterer.

In the 20th century, Maribor became the leading city in the Yugoslav textile industry. In 1928, Carl Thoma and his employees founded a factory for the production of luxury silk fabrics in Maribor. In 1937, the company employed around 400 workers, 350 of whom were weavers. Women played an important role in the laborious process of weaving and made up 75% of the workforce.

The factory received its first looms from then Czechoslovakia. These looms, were originally used to weave fine cotton fabrics, but were later adapted to the intricacies of silk weaving. Before the Second World War, the company produced between 20 and 30 % of all fabrics from silk. Interestingly, they used undegummed silk for the warp and degummed threads for the weft.

In 1947, Carl Thoma's company merged with two others and was renamed "Die vereinigten Seidenfabriken" (The United Silk Factories). After the 1950s, the factory became a kind of cooperative property and was renamed to "Svila" Maribor. It operated until its bankruptcy in 2005. For a short time, silk fibres and threads were used to produce rich silk fabrics for various markets across Europe, but this was soon replaced by artificial silk and rayon threads.

Dyeing silk in a factory Svila, 1964 (Photo / **J. Šen**).

The visual identity of the Svila company (1928 - 2005) (Source / **J. Šen**)

Silk printing in a factory Svila, 1964 (Photo / **J. Šen**)

Local mulberry cultivation

The picture shows a group of people in traditional costume. All the members in the photo are wearing at least one piece of silk fabric. (the skirts, the black silk apron, silk scarf, etc.). The front of the waistcoat is made of velvet with embroidered flowers, the back is made of fabric, but can also be made of other materials such as silk or wool, 1943 (Source / **S. Knap**, http://stareslike.cerknica.org)

The beginnings of mulberry cultivation in the Goriško/Gorizia region date back to the 16th and 17th centuries as this area had direct economic and cultural links with Friuli Venezia Giulia, where the sector was already well established. It was also assumed that the mulberry trees would best able to withstand the mild winters of the sub-mediterranean region.

The first state incentives came from Ferdinand III, in the mid-17th century, with the aim of achieving greater independence from expensive silk imports. A hundred years later, the Empress Maria Theresa of Austria and her son, Joseph II. established a state support programme and took the necessary steps to promote their own production of this luxury product. The efforts of Maria Theresa's government to make mulberry cultivation a decisive factor in the agricultural and economic regeneration of the Goriško-Gradiška/Gorizia-Gradisca region overcame the resistance of landowners, communities, and colonists to the establishment of mulberry plantations on plots and uncultivated land. The Economic Magistrate of the Goriško-Gradiška/Gorizia-Gradisca region wanted to raise the status of sericulture in the region to the same level as in Italy or France. In most cases, the communities themselves took over the management of the mulberry plantations, mainly to limit the claims of many individuals who had been authorised by the Economic Magistrate to plant mulberry trees on communal land. Mulberry trees were planted along roads, in fields and as supports for vines, especially in the lowlands and in the Alpine foothills. The mulberry trees planted in the landscape and around the houses marked the cultural landscape for centuries. Sericulture became the most important agricultural sector in the valleys and hills of the Goriška/Gorizia, alongside viticulture, and the suitability of mulberry cultivation was one of the main topics of agricultural literature and academic discussions of that time.

During the reign of Maria Theresa, the planting of mulberry trees was also greatly promoted in the areas of Upper Carniola and the Savinja Valley (Lower Styria). In 1756, all farmers were divided into three categories according to the size of their land and were ordered to plant mulberry seedlings. Similar attempts were made in Carinthia in 1763, when the trade consuls were instructed to speed up the spread of sericulture and to plant different tree species together with mulberry trees on all royal lands, especially along roads and on degraded land. The planting of mulberry trees was largely financed by the government to the feudal lords, which in turn distributed prizes, to the lower classes – mostly peasants.

The Napoleonic wars exhausted the Goriška/Gorizia region and severely damaged the mulberry plantations. During the last retreat, the troops cut down and burnt many old mulberry plantations. In some cases, the farmers cut down the trees because their income was lower than expected. Therefore, during this period, agricultural societies were responsible for growing mulberries in nurseries. In addition to the local white mulberry trees, which were mainly propagated by seed, special mulberry varieties such as 'Morettiana', 'Giazzola' and the 'Philippine' were introduced. The owners of large estates established new mulberry plantations, especially from 1830. Princess Eliza Baciocchi Bonaparte, the sister of Napoleon Bonaparte, had tens of thousands of mulberry trees planted in the Goriško-Gradiška/Gorizia-Gradisca region and organised the establishment of a nursery in the Soči canal (on the Soča River) with around 60,000 seedlings. In 1833, the first mulberry trees were planted in Čezsoča near Bovec (Julian Alps) under the auspices of the Agricultural Society,

At that time, Agricultural Societies also recommended silkworm rearing in the pre-alpine and alpine areas of the Slovenian regions. It was thanks to them that interest in sericulture in the Slovenian alpine regions increased in the 1830s. To this end, the Carniolan Agricultural Society established a mulberry nursery on its property and sent many seedlings to Dolenjska/Lower Carniola, where they received special attention. In Dolenjska/Lower Carniola, near Ljubljana, the landowners expanded the mulberry plantations, but in Upper Carniola (Gorenjska) they were less successful.

Moreover, mulberry trees and sericulture were an important part of the daily life of railway workers, as evidenced by the fact that around 200,000 trees were planted along the tracks of the Southern Railway connecting Frohnleiten (Austria) with Ljubljana. This practise was abandoned after 1854, when the French took over the railway company.

In Lower Styria, the history of mulberry cultivation and selection is intricately connected with the fascinating agricultural rise of the Novo Celje mansion, known as the Styrian Eden, which was significantly promoted by Archduke John of Austria (1782–1859, brother of the Austro-Hungarian emperor Francis II). In 1843, the owner of the Plevna mansion embarked on a remarkable endeavour by planting an initial 23,000 mulberry trees. Dr. Anton Perinello contributed to the plantation's diversity by acquiring mulberry trees of semi-low and medium cutting form from Lombardy and Rome. The entire plantation at Novo Celje consisted of ten large plantations, five of which followed the Venetian style known as 'La Piantata Veneta'. Straight rows of mulberry trees alternated between semi-low and high cutting form, and accompanied by high-quality vine varieties, such as 'Burgundian' and 'Moselle'. This systematic approach ensured a balance between high and semi-low trees and a harmonious integration of the vines. All the mulberry trees were grafted above the root crown, demonstrating advanced horticultural techniques. These trees were mainly of the 'Giazzola' variety, followed by 'Filippine' variety, which at the

Mulberry plantation near Brestovica in the Karst (Source / **V. M. Ipavec**, 2008)

The village inn in Skopo in the Karst around 1960 (Photo / **P. Falatov**, Source / **V. M. Ipavec**, 2008) time was renowned for its exceptional leaf yield and quality. Records indicate that a range of organic fertilisers were used on the plantation, including bovine hair, hooves, waste from the reeling, and bone meal from Graz, which further increased the fertility of the soil.

In the spring of 1845, Novo Celje extended its plantations to the Turnišče mansion in Ptuj, by importing 2,000 mulberry trees from Rome using Perinell's method. The plantation at the Turnišče mansion was a further commitment to use state of the art practices in sericulture.

In 1896, Ivan Bolle's book 'Teachings on moriculture (Murvoreja)' provided valuable insights into mulberry cultivation, propagation, grafting techniques and pruning used in Slovenia. Sericulture and the cultivation of mulberry trees experienced a significant decline after World War II. Historical collections from the Sericulture Station in Gorizia, the plantations of Novo Celje, Plevno and Turnišče did not survive this period.

Before the Second World War, Andrej Mikuž worked as an agricultural promoter at the agricultural school in Gorizia/Gorica, teaching the rural population about new cultivation methods. To that time Evgen Mayer was the owner of Lože Castle in the Vipava region, where he began to introduce new varieties of fruit trees, including mulberry. He reported that the unfavourable conditions for mulberry cultivation before, during and after the war, as well as the political situation in the post-war period, had reduced the number of mulberry trees by about a half.

In 1948, the tree nursery of the Ozeljan State Estate took over the mulberry propagation. The chateau and the land were transferred to the Secondary School of Viticulture and Fruit Growing in Lože. Andrej Mikluž, head of the estate, was also active in the organisation of sericulture in the Vipava Valley and the Karst region.

Mulberry row in front of the Church of the Assumption of Mary, Bertoki, Coastal region (Photo / **A. Hodalič**)

Decline of sericulture in the 20th century

After the Second World War, the promotion of silkworm rearing was included in a five-year development plan to promote the textile industry sector. Intensive efforts were made to revitalise silkworm rearing in the Littoral, especially in the Goriška region. In 1948, a Sericulture Station was established at Rafut, near Gorizia/Gorica. Shortly afterwards, it was moved to the state estate in Ozeljan (Vipava Valley). Evgen Mayer visited agricultural cooperatives and primary schools to reach as many people as possible. Andrej Mikuž, head of the state estate in Ozeljan, also drew the attention of the population of the Goriška region to the importance of sericulture and its technologies and visited individual rearers during the season.

Sericulture was mainly promoted in the lowlands, in the lower Vipava valley, where the spring cold prevented the development of fruit growing and viticulture. Prominent vine and fruit-growing areas were not included, as sericulture there would interfere with spring work, especially spring spraying of vine and cherry harvesting. According to Mayer's findings, the Karst was very suitable for sericulture, while mulberry trees in better locations could also be used for reforestation and as a protective belt against storms. There were also favourable conditions for the development of sericulture on other southern slopes of Goriška.

Sericulture survived the longest in the plane between the Soča and Vipava rivers, on the so-called Goriška Ravana and the lower Vipava valley. The rearing season took place mainly in the 'dead period' before the period of haymaking and cereal harvesting. The last silkworm rearing cycles were performed at the beginning of the 60-ies.

Local women harvesting cocoons in Vrtojba in the early 1950s (Source / **V. M. Ipavec**, 2008)

A part of the exhibition organised by Bobbin Lace Society of Ljubljana for the Mid-meeting exhibition of the Aracne project in Maribor. Forty-five lacemakers made lace using the old pattern of the company DOM Ljubljana. Each lace piece features a unique silk filling, with the interpretation left to the creativity of the individual lacemakers. The silk used in the process is sourced from the Slovenian silk rearers or commercially available processed and spun silk thread
(Photo / **S. Strgulc Krajšek**)

Attempts at renewal in the 21st century

The first attempts to revitalise sericulture were made within the framework of a joint Hungarian-Slovenian research project [Influence of feeding silkmoth (*B. mori* L.) hybrid larvae with leaves of old local Hungarian and Slovenian mulberry (*M. alba* L.) genotypes on the development and health status of larvae], which brought together researchers from the fields of botany and veterinary medicine, and aimed to inventorise existing genetic resources of historical mulberries in Slovenia and Hungary, establish collections and identify key metabolites in the leaves for the development and health of silkworms. During the project, first attempts to reintroduce silkworm rearing were made and the first silkworm rearers from different regions used local mulberry trees and started to plant new mulberry varieties.

As an advisory institute for silkworm breeding was needed, the Institute for Sericulture and Silk Processing (ISS RLB Lab) was founded in 2018 to provide theoretical and practical support, advice, education and training to current and future Slovenian silkworm rearers. The institute has established a network of scientific, professional and technical colleagues and pilot silk farmers based on the research results and gained experience under Slovenian environmental conditions, supported by CREA Padua. The ISS RLB carries out various projects related to silk production. These include preparing and conducting practical pilot experiments, analysing the feasibility of transferring the developed solutions to rearers on a larger scale and disseminating the results. Since 2016, sericulture attempts and traditional silk processing have been presented in workshops, various exhibitions, fairs and publications by the ISS RLB Laboratory, the University of Maribor team, the restoration workshop of the Regional Museum of Ptuj-Ormož, as well as by dedicated rearers and artisans.

The most notable projects include the contribution to the Idrija Lace Festival with bobbin lace made by certified lace makers using silk yarn from Slovenian cultivated silk, the contribution to the European Heritage Days and the exhibition "'Skills and Secrets of Master Weavers" organised by the Ptuj-Ormož Regional Museum. In this exhibition, you can admire the first attempts of Slovenian silkworm rearers to produce and twist their own silk thread, as well as their own products, namely knitwear, bobbin lace, embroidery and advanced home design products. In addition, Slovenian silkworm rearers are also involved in the preservation of the old mulberry trees in the region. Further activities of rearers include restoration and promotional activities for the local public, in the form of workshops for schools and the local community.

Part of the exhibition entitled "Fairy Tale Threads" at the Ormož Library (January-March, 2024). In addition to the National Geographic magazine presenting the article Silk Thread Unveiled, historical documents showing the revival of sericulture in the Ormož region are also presented. The exhibition includes earrings, bracelets, bobbin lace and hand-spun silk threads by rearer Maja Botolin Vaupotič and bobbin lace maker Majda Štampar, Velika Nedelja
(Photo / **M. Botolin Vaupotič**)

Silk grower Marko Balažič
(Photo / M. Balažič)

The conservation of silk fibres, especially those treated with metal salts, is a central theme of the SAFESILK project (1. 1. 2022–31. 12. 2024), which is led by the Heritage Science Laboratory of Ljubljana. Another project is AlpTextyles (1. 11. 2022–31. 10. 2025), whose main objective is to create an inventory of various sustainable textile crafts and practices in order to create a sustainable and circular textile economy in the Slovenian Alpine sector and to develop textile chains that reduce CO2 emissions.

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Silk grower Janez Škalič from Goričko, Prekmurje.
(Photo / A. Hodalič)

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SILK CRAFT, MANUFACTURE AND SILK ART MUSEUMS

1. Slovene Ethnographic Museum, Ljubljana

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2. Technical Museum of Slovenia, Bistra

https://www.tms.si/en/
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3. Slovene Museum of Christianity Stična, Stična

https://www.mks-sticna.si/eng/home
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4. Kočevje Regional Museum, Kočevje

https://www.pmk-kocevje.si/index.php
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5. Maribor Regional Museum, Maribor

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Georgia: State Silk Museum, Georgia.
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