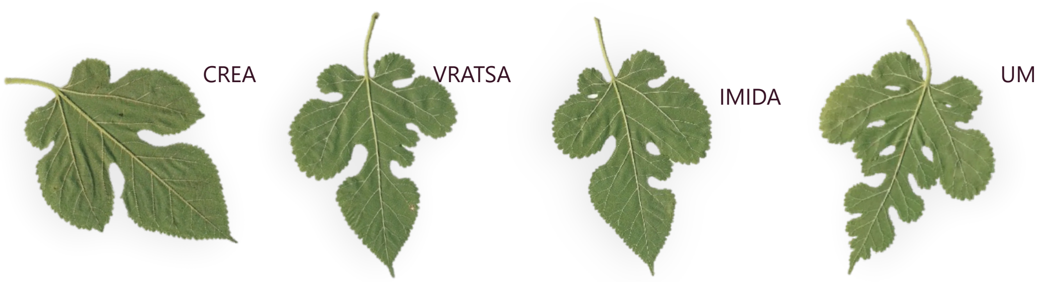
DEVELOPED UNDER THE RECREATION OF EUROPEAN MULBERRY HERITAGE

Catalogue of Mulberry Varieties

Documenting the Morphological Diversity of Traditional Mulberry Varieties from Germplasm Collections of Aracne Countries



ABOUT THE PROJECT

Description of the project

The ARACNE project focuses on the cultural heritage of European silk production and its preservation, protection, and valorisation; it aims to reinvigorate traditional skills through the adaptive reuse of common cultural and artistic legacies and to shape a silk-linked European cultural identity. The production, past, and present development of the silk sector can again serve as a common basis for a future European Silk Route, intended as a cultural itinerary across Europe. To create a wide and well-connected network that, starting from the historical path followed by Marco Polo in his travels to the East, even includes the routes of silk production and commercialisation in Europe in the following centuries.

NOTES

Introductory notes

The most significant mulberry collections among the ARACNE partner countries are maintained at **CREA Padua**, **Italy** (Consiglio per la Ricerca in Agricoltura e l'Analisi dell'Economia Agraria, Padova), **SCS Vratsa, Bulgaria** (Nauchen Tsentar Po Bubarstvo Vratsa), **UM, Slovenia** (University of Maribor, Faculty of Agriculture and Life Sciences), and **IMIDA, Spain** (Instituto Murciano de Investigacion y Desarrollo Agrario y Medioambiental, Murcia).

The systematic evaluation of these collections—through monitoring vegetative and reproductive traits using standard mulberry descriptors, complemented by genetic analyses—is essential for supporting selection and propagation programmes related to sericulture, landscape planning, and sustainable use of mulberry resources. The growth and yield of mulberry plants are significantly influenced by environmental conditions. Therefore, systematic documentation of morphological and phenological traits over the three-year duration of the ARACNE project plays a critical role in maximising the use of these resources and selecting high-yielding morphotypes. This documentation equips rearers/farmers with the detailed information needed for decision-making. Sharing germplasm information is vital not only for countries practising sericulture but also for those using mulberry leaves as animal fodder, mulberry fruits as food, and other by-products for various purposes. Furthermore, characterising germplasm is crucial to identifying individual genotypes, understanding variability among accessions, and facilitating comparisons for further research and practical use. This process involves systematically documenting highly heritable traits, enabling the identification of diverse mulberry germplasm and supporting the development of a robust database for research and moriculture initiatives. The Mulberry Varieties Catalogue presents mulberry genotypes maintained in the collections of CREA, Vratsa, IMIDA, and UM. The varieties were systematically monitored using **UPOV Mulberry descriptors**, basically modified as described in **Guidance model to collect mulberry samples**, which covered trunk, shoot, bud, inflorescence, infructescence, and phenological traits, as well as growth and yield attributes. Observations were conducted over the period from 2023 to 2025. These results will be integrated with genetic analyses to deepen our understanding of the genetic relationships within the available germplasm, recognising it as a valuable component of the European sericultural heritage.

PARTNERS INVOLVED

Partners involved in the mulberry varieties' catalogue

CREA Padua, Italy - Consiglio per la Ricerca in Agricoltura e l'Analisi dell'Economia Agraria

The current collection consists of 68 varieties. 50 varieties belonging to the ingroup M. alba s.l., 14 varieties assigned to *M. indica* s.l., 3 varieties *M. rubra* cf. or hybrids between *M. alba* and *M. rubr*a. M. nigra is represented by one genotype. The varieties originate from Italy, France, Spain, China, Japan, and Brazil.

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SCS Vratsa, Bulgaria - Nauchen Tsentar Po Bubarstvo Vratsa

The germplasm maintains 180 accessions. 96 accessions are selections of the SCS Vratsa breeding programme. Fourteen accessions are categorised as *M. alba* s.l., 80 genotypes are regarded as hybrids between M. alba and M. indica with no clearly defined genetic background (Morus sp.), and two varieties are categorised as *M. indica*.

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University of Maribor, Faculty of Agriculture and Life Sciences (UM FKBV)

The collection is divided into 3 sections. The 1. section comprises sericultural varieties of different origin (8 varieties, 272 trees), the 2. section is represented by old local Slovenian (80 genotypes) and Hungarian varieties (127 genotypes), the 3. section is represented by varieties for fruit production (20).

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IMIDA Murcia, Spain - Instituto Murciano de Investigacion y Desarrollo Agrario y Medioambiental

The collection is represented by 35 varieties. Of these, 31 varieties belong to M. alba s.l. The ingroup *M. indica* s.l. is represented by three varieties of 'Kokusou', namely Kokusou 20, 21 and 27. In addition, one local *M. nigra* is part of the collection.

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CREA

Centro di Ricerca per l'Agricoltura e Ambiente, Padova, Italy

M. indica (syn. M. bombycis) **'Akagi'**

M. alba **'Aoba Nezumi'**

M. alba **'Arancina'**

M. alba **'Ascolana'**

M. alba **'Badena Tout'**

M. alba **'Cabassette'**

M. indica (syn. M. latifolia) **'Dai Kokusō 70' (syn. 'Nihou Kokusō 70')**

M. indica (syn. M. latifolia) **'Dai Kokusō' (syn. 'Nihou Kokusō')**

M. indica (syn. M. bombycis) **'Date Akagi'**

M. indica (syn. M. bombycis) **'Enshu-Takasuke'**

1 2 3 … 6 →

Centro di Ricerca per l'Agricoltura e Ambiente (CREA-AA), Padova
Director: dr. Silvia Cappellozza, silvia.cappellozza@crea.gov.it
Curator: dr. Gianni Fila, gianni.fila@crea.gov.it
Postal Address: Via Eulero 6a, 35143 Padova, Italy

The collection and experimental field of the Laboratory of Sericulture of CREA-AA, in Padua (latitude 45.399080, longitude 11.834279), extends over about two and a half hectares, conserving more than 70 varieties of mulberries. The varieties originate from Italy, France, Spain, China, Japan, and Brazil. The collection comprises 50 varieties belonging to the ingroup *M. alba* s.l., 14 varieties assigned to *M. indica* s.l., three varieties *M. rubra* cf. or hybrids between *M. alba* and *M. rubra*. The most widely cultivated varieties (> 20 trees) are 'Florio', 'Morettiana', 'Kokusou 20', 'Kokusou 21', 'Ichinose', 'Arancina', 'Limoncina', and 'Restelli'.

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VRATSA

Nauchen Tsentar Po Bubarstvo Vratsa, Bulgaria

Morus indica **'Adreulu'**

M. indica (syn. M. multicaulis var. planifolia) **'Armenia'**

M. alba **'Azerbaijan 20'**

M. alba **'Azeri tut'**

Morus indica s.l. **'AzNIISh 7'**

Morus indica **'Camil tut'**

M. indica (syn. M. latifolia) **'Digmuri'**

M. alba **'Emin tut'**

M. indica (syn. M. kagayamae) **'Georgia'**

Morus indica **'Gezal tut'**

1 2 3 … 7 →

Nauchen Tsentar Po Bubarstvo Vratsa (Scientific Center on Sericulture, SCS)
Curator: Prof. Dr Panomir Tzenov, panomir@yahoo.com
Postal Address: 24 Mito Orozov Str., 3000 Vratsa, Bulgaria

Established in 1896 the Scientific Center on Sericulture – Vratsa (SCS) is now the biggest center in Bulgaria conducting various activities for sericulture industry development. There are presently 205 mulberry accessions in the germplasm from nearly all countries dealing with sericulture from the temperate and sub-tropical climatic zones and the germplasm that are yearly screened for morphological and phenological parameters. A total of 70 mulberry varieties of different origins were included in the morphological study, following the ARACNE proposed descriptor database. Most of them are Bulgarian varieties of local origin or selections of the breeding programme (24), introduced varieties that were included in the study are from Georgia (13), followed by those from Uzbekistan (12), from Azerbaijan (11), Ukraine (6), Armenia (4) and from Romania (1).

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IMIDA

Instituto Murciano de Investigacion y Desarrollo Agrario y Medioambiental (IMIDA), Murcia, Spain

M. alba **'Balsa'**

M. alba **'Borde negra'**

M. alba **'Borde perejilera'**

M. alba **'Bresciana' (Italiana 6)**

M. alba **'Brianzola' (Italiana 1)**

M. alba **'Brianzola' (Italiana 14)**

M. alba **'Ciaroca' (Italiana 2)**

M. alba **'Cine'**

M. alba **'Cristiana Precoz'**

M. alba **'Cristiana'**

1 2 3 4 →

Instituto Murciano de Investigacion y Desarrollo Agrario y Medioambiental

Curator: Ana Pagan Bernabeu, anapagan@um.es

Postal Address:C/Mayor s/n 30150, La Alberca, Spain

default

IMIDA in Murcia (Spain) preserves a diverse mulberry collection at the former Sericulture Station of Murcia (37.939636° N, −1.133487°). Located in an urbanised area, the collection includes 35 varieties of Morus, mainly M. alba and M. indica, originating from Italy, Spain (local varieties), and Japan, as described in the catalogue. The Italian accessions were obtained from the Experimental Sericulture Station in Padua around the 1920s, which is also approximately when the Japanese 'Kokusou' varieties were introduced. Overall, Italian accessions dominate, followed by Spanish and then Japanese Kokusou varieties.

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UM
Slovenian varieties

University of Maribor, Faculty of Agriculture and Life Sciences, Pivola, Slovenia

M. alba **'SI-SE/BK 282'**

M. alba **'SI-SE/BK 290'**

M. alba **'SI-SE/BK 292'**

M. alba **'SI-SE/BK 5'**

M. alba **'SI-SE/BK 6'**

M. alba **'SI-SE/BK 7'**

M. alba **'SI-SE/BK 7/2'**

M. alba **'SI-SE/BK 8'**

M. alba **'SI-SE/BK 9/1'**

M. alba **'SI-SE/BK 9/2'**

1 2 3 … 7 →

UM
Hungarian varieties

M. alba **'AT-BU/1049'**

M. alba **'HU-2'**

M. alba **'HU-4'**

M. alba **'HU-BA/2111'**

M. alba **'HU-BA/2122'**

M. alba **'HU-BA/2126.14'**

M. alba **'HU-BA/2132'**

M. alba **'HU-BA/2153'**

M. alba **'HU-BA/2174'**

M. alba **'HU-BAZ/1219'**

1 2 3 … 7 →

Reference varieties

M. alba **'Agathe'**

Morus alba s.l. **'Akagi'**

Morus sp. **'Big ten'**

M. indica s.l. **'Coree'**

Morus alba **'CREA – fruit selection, Frutto'**

Morus alba x M. rubra **'French Hybrd'**

Morus alba s.l. **'Gelicine'**

Morus alba **'Gelso rosso'**

Morus alba **'Gleichenberg'**

Morus indica **'HU-BA/2179'**

1 2 3 4 →

*Abbreviations UM: SI- Slovenian varieties: SM – Submediterean region, SP – Subpannonian region, SE – South Eastern region. HU – Hungarian varieties: BA – Baranya, BAZ – Borsod-Abauj-Zemplen, BE- Bekes, GMS – Gyor-Moson-Sopron, PE – Pest, SO – Somogy, TO – Tolna, VA- Vas, VE – Veszprem, ZA- Zala;

In Slovenia, the relevant mulberry germplasm collection is maintained at the Faculty of Agriculture and Life Sciences University of Maribor (UM). It extends over 0.6 ha and is organised into three sections. The first is represented by the traditional sericultural mulberry varieties obtained from the germplasm collections of the Sericultural Institutes CREA Padua and SCS Vratsa. In the continuation of this collection, we grow vegetatively-propagated trees derived from the local historical Slovene and Hungarian trees, which were obtained during the inventory of the mulberry gene pool within the Slovenian-Hungarian research project between 2015-2018 (ARIS N1-0041) and Aracne Horizon (GA 101095188) project . The third section is represented by varieties for fruit production.

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Collections

- CREA
- SCS VRATSA
- IMIDA
- UM

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ITALY

History of the development of mulberry germplasm resources in Italy

In Italy, the first species of mulberry to be introduced was *Morus nigra*, 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. The oldest available documentation attesting to the presence of *Morus alba* in Italy dates back to 1434. This species was then introduced simultaneously with the activation of the silk industry and spread quite rapidly throughout Italy.

Despite the great importance of mulberries for sericulture, they were never the subject of significant scientific research or genetic selection programs. Only in the 19th century, with the shift towards the industrialisation of sericulture, did they begin to set up specialised facilities with selected varieties, spread throughout the country. Until then, extensive use was made of local genotypes. Between the 1930s and 1950s, new varieties were imported from abroad, particularly from the Far East (mainly Japan).

With the decline of sericulture in the course of the 20th century, the specialised plantations also disappeared, with the survival of only sporadic solitary trees and spontaneous progeny in marginal areas of the countryside.

In Italy, the most relevant mulberry germplasm collection is the one belonging to the Sericulture Laboratory of CREA, the Research Centre of Agriculture and Environment located in Padua. The institute was founded in 1871 in the very centre of the town, was then moved to the suburbs in 1923. It was around that time that the first mulberry plantation was established in the new location, next to the institute, but most of the plants in the current collection were planted after 1958, when the Ascoli Piceno Sericulture Station ceased its activities, and its former director, Porzia Lorenza Lombardi, transferred its collection here, thus making the Padua Station the only research hub on silkworms and mulberries.

Currently, the collection extends over about two and a half hectares, conserving overall 68 varieties of mulberries, of which 21 are of Italian origin. The core collection is concentrated in a parcel where an average of 5-10 trees for each accession is maintained. The rest of the area is occupied by larger plantations, with plots of 100-500 m2, where trees intended for the production of leaves for silkworm rearing are grown. The most widely cultivated varieties (> 20 trees) are 'Florio', 'Morettiana', 'Kokusou 20', 'Kokusou 21', 'Ichinose', 'Arancina', 'Limoncina', 'Restelli'.

Initially, the creators of the collection were concerned with preserving varieties belonging to all the then known major species of *Morus*, and so the following species were represented: *M. alba* (L.), *M. nigra* (L.), *M. multicaulis* (Perr.), *M. latifolia* (Poir.), *M. bombycis* (Koidz), *M. kagayamae* (Koidz). However, according to the most recent studies, which employ molecular methods for phylogenetic reconstruction (Zeng et al. 2015), it can be said that all accessions actually fall within the scope of *M. alba*, *M. nigra* and *M. rubra*.

The plants cultivated in the collection plot are grown in a vase shape, which is the most suitable form for obtaining indications on the natural behaviour of the different varieties. The plants are not irrigated, and pruning is generally carried out at the end of winter or between spring and the beginning of summer. Organic fertilisation is the only one practised, while weeds are mechanically controlled.

During the period 2020-2023, some plots with old mulberries were uprooted, to be gradually replanted with young plants in order to refresh the collection. In 2023, after a suitable resting period for the soil, the first replanting began. In the new collection, the number of plants conserved per accession increased from 5 to 10. Apart from the known varieties, a space is dedicated to host trees found in the territory, cloned from centuries-old trees, in an effort to reconstruct a genetic heritage based on ancient populations, with a view to improving plantations in terms of resilience to climate change and variability of leaf quality, even for applications other than silkworm rearing.

Development of mulberry germplasm resources in Italy

Documented activities of mulberry genetic improvement are not known in Italy at least until the eighteenth century. For a long time, farmers predominantly multiplied the mulberry by seed, believing that this would result in more robust and more productive plants, and over time, this led to the differentiation of local populations of ‘wild mulberry’ (‘Selvatico’ in Italian). Grafting was also used to multiply certain prized lines or those that could hardly be propagated by seed, and even for these, distinct populations were formed at a local or regional level.

Only towards the end of the eighteenth and the beginning of the nineteenth century did they begin to introduce new varieties, mostly imported from abroad. This was due to the need to renew the genetic basis of the plantations because of the incidence of new diseases and parasites that affected the mulberry, and on the other hand, to create specialised mulberry orchards to follow the trend towards the industrialisation of sericulture.

The most extensive and oldest list of varieties is that reported by Jacopo Alberti in 1773, which encloses 22 varieties of white mulberry. Shortly thereafter, they began to import and study exotic varieties, which include the 'Morettiana' mulberry, obtained in 1780 in Milan from seeds coming from India, while the importation of the "Filippine" variety, imported from the Philippines and which had very wide distribution, dates back to 1825. Another variety to mention is the 'Cattaneo', released in 1865 and recommended for repopulating cultivations decimated by parasites. The 'Restelli' variety dates back to the early 1900s, introduced to combat infestations of Pseudaulacaspis pentagona.

In general, in these years, the selection criteria were based essentially on productivity, which also depended on disease resistance, and on the quality of the leaf, considered essential for the production of quality silk. In more recent years, importance was also given to the earliness of sprouting, a sign of sericulture conducted with planning and specialisation criteria.

After the decline of sericulture in the course of the 20th century, in Italy, there were no more significant genetic improvement activities concerning the mulberry tree. At the Padua Station, the mulberry has been essentially seen as a forage tree for silkworm rearing, and it has never been the subject of dedicated research activities, apart from agronomic experiments, targeting cultivation and propagation techniques rather than the improvement of the genetic basis.

However, an activity has been initiated to recover genotypes widespread across the national territory, through territory exploration, with the goal of expanding the genetic base of the collection, and mainly aimed at reconstituting populations particularly adapted to pedoclimatic conditions. For this reason, particular attention has been paid to the recovery of clones obtained from centuries-old specimens, which, precisely because of this characteristic, present high probabilities of adaptation to climate variations and environmental stresses.

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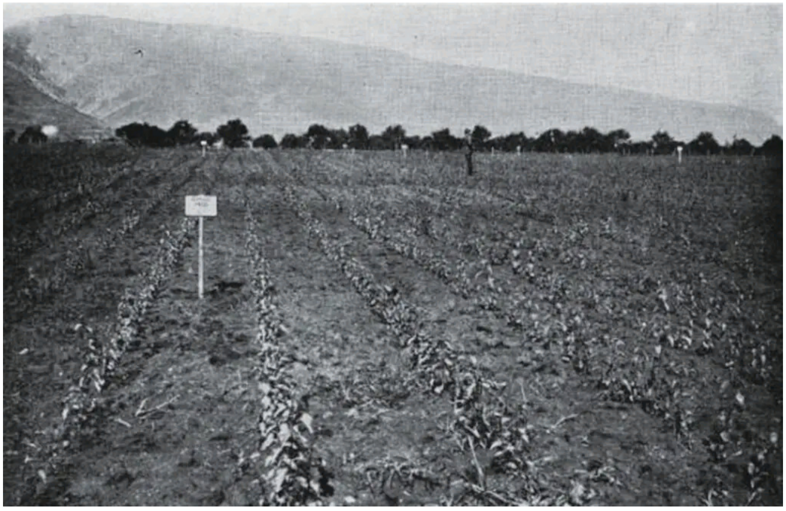
BULGARIA

History of the development of mulberry germplasm resources in Bulgaria



Established in 1896, the Scientific Centre on Sericulture in Vratsa (SCS) has grown to become the largest centre in Bulgaria dedicated to the advancement of the sericulture industry. The Research Department at SCS comprises four specialised laboratories: the Mulberry Selection and Agronomy Laboratory, the Silkworm Genetics Laboratory, the Silkworm Selection and Egg Production Laboratory, and the Silkworm Rearing and Cocoon Processing Laboratory. These laboratories focus on a range of research activities, including genetic studies on breeding technologies for the development of new silkworm lines, breeds, and hybrids; technology for silkworm egg production; prevention of silkworm diseases and pest control; selection and cultivation of mulberry; cocoon and silk processing; as well as sericulture economics and management.

The SCS prides itself on maintaining an extensive collection of more than 200 mulberry varieties and over 70 silkworm strains and lines. These have been gathered from both domestic and international sources and are continuously bred to enhance their genetic traits. This comprehensive approach ensures that SCS remains at the forefront of sericulture research and development, contributing significantly to the industry's growth and sustainability.

In Bulgaria, mulberry has grown naturally since ancient times, and now the following species are available in the country: *M. alba*, *M. indica* (var. *M. latifolia*, *M. bombycis*, *M. kagayamae*, *M. multicaulis*), *M. rubra* and *M. nigra*. At the beginning of the 20th century, almost all the mulberry trees and plantations in Bulgaria were of the local 'wild type' variety, characterised by excellent adaptation to the climatic and soil conditions, but a low leaf yield. Twelfe mulberry varieties were introduced for the first time from Italy in 1930. After that mulberry varieties have been imported many times from the Soviet Union (in 1956; 1958; 1965; 1967), Japan (in 1963; 1970; 1974), Romania (1964), China (1967; 1982), Egypt (1998), Ukraine (1998) and Azerbaijan (2004).

For the enrichment of mulberry germplasm, SCS Vratsa has organised several field trips for collection of accessions. The exotic accessions imported from Italy and those collected in Bulgaria until 1932 were characterised and evaluated and the accessions N3, N21, N24, N26, N101, N106 and N112 were recommended for use at the field level. From indigenous accessions, collected in 1950 and 1953 the accessions N 59, N51, N33 and N53 having higher leaf yields were selected. In the period 1940-1950 several mulberry hybrids between the female varieties N24, N103, N106 and the male varieties N3, N21, N62, N112 were obtained. As the best combinations, N24 x N3, N103 x N3 and N106 x N3 were recommended.

During the period 1956-1967 the mulberry varieties 'Kokusou 21', 'Kokusou 27' and 'Kinryu' were introduced from Japan through Soviet Union. During this period further varieties N3, N24, N59, N101, N106, 'Adreuli', 'Pobeda', 'Tbilisuri' and 'Kokusou 70' were tested in the main sericulture regions of Bulgaria. The varieties N106, 'Kokusou 70', 'Pobeda' and 'Tbilisuri' gave the

best results and were approved by the government for commercial sapling production.
In the period 1967-1977 the hybrid offsprings of the varieties 'Georgia', 'Kinryu', 'Kokusou 20', 'Kokusou 27', N24 and N106 under natural pollination were investigated. It was found that the offsprings of 'Georgia', 'Kinryu' and N24 had the largest percentage of unlobed leaves, 89%, 67 % and 63 % respectively. During the period 1976-1978 new local varieties 'Vratsa 1' and 'Vratsa 18' were selected at SCS Vratsa, tested and approved for commercial use.

New mulberry accessions were created by using the methods of experimental polyploidy and hybridization. Penkov (1980) made a hybridisation between the accessions N3, N116, N118, and N120 belonging to the species *M. alba* and *M. indica* (*M. kagayamae* and *M. latifolia*). A high percentage of trees with unlobed leaves manifested in the hybrids N24 x N116 – 90 %, N117 x N3 – 85 %, and N119 x N3 – 75%. These hybrids were approved by the government as hybrid varieties (Hybrid 50, Hybrid 78 and Hybrid 96) for commercial use in 1980.
The research work completed in 1981 proved that the F1 mulberry offsprings had very high variation in leaf lobation type and the mother variety influenced the leaf lobation type in the progeny to a greater extent. The leaf size was inherited intermediately in F1.
In 1995 a methodology for characterisation and evaluation of mulberry accessions was developed by Petkov (1998). Now the research work on mulberry selection is considered a very important activity at SCS Vratsa. It is necessary to continue the collection of new mulberry varieties both exotic and indigenous. In the period of 1998 – 2005 more than 2500 hybrid seedlings have been obtained, planted and evaluated.
The future direction of the breeding work should be the so called 'far' hybridization between varieties from different geographical regions, different species and especially between varieties having different chromosome numbers. As a result of the breeding work the highly productive mulberry varieties 'Vratsa 1', 'Vezletz' and 'Vratsa 18' were selected at SCS Vratsa which could be of interest for introduction in other countries as well.

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SPAIN

History of the development of mulberry germplasm resources in Spain

The beginnings of sericulture during the Arab rule were carried out by feeding the silkworms with mulberry leaves of moral or black mulberry, *Morus 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 *Morus alba* began to be cultivated in Valencia and Murcia. This has a more tender and palatable leaf for the silkworms, and it is more nutritious. As a result, it produces better quality silk. The harder-leaved *Morus nigra*, on the other hand, is a very resistant species that is 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 growers 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, as they considered its quality to be superior. 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 *Morus alba* was imposed and *Morus nigra* became marginal, being cultivated only on the island of La Palma in the Canary Islands until now.

We do not know exactly which varieties of mulberry were cultivated in the distant past. Over time, however, two types of mulberry trees have been selected as native to Spain. One is the 'Valenciana' type, predominant in Valencia, which is not a single genotype but a family of 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 creation of the Sericulture Station, these two types and their hybrids spread all over Spain, as one of its tasks was to maintain nurseries and distribute free seedlings to all growers who requested them. During decades, 20,000 seedlings a year were distributed.

Regarding the silkworm breeds used in ancient times, we can only mention as indigenous the race 'Sierra Morena', of yellow silk, traditional in the south of the country. However, almost all old breeds were progressively displaced by new Japanese high-yield breeds introduced and promoted by the Sericulture Station in the middle of the 20th century.

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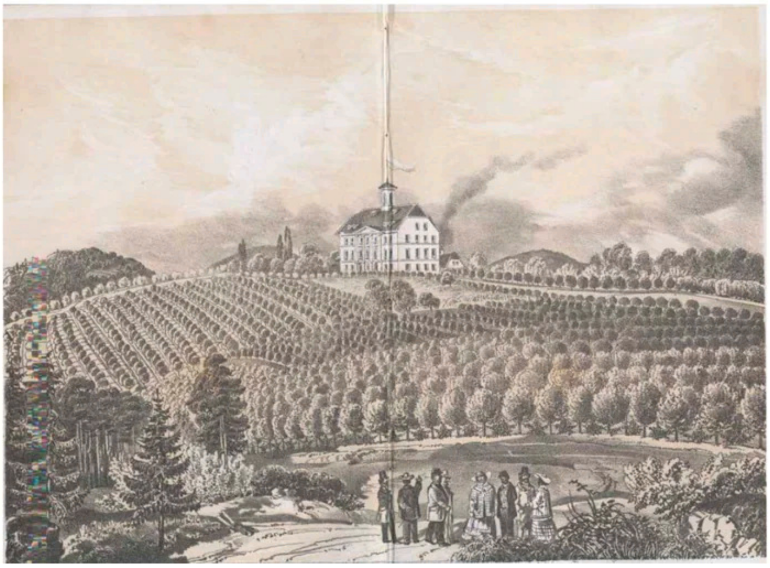
SLOVENIA

History of the development of mulberry germplasm resources in Slovenia

The very long period of mulberry cultivation in Slovenia has led to the emergence of genotypes with different fruit characteristics through agronomic selection, as mulberries were mainly propagated by gamic propagation in the past, which increased diversity. Documented activities of mulberry genetic improvement in the form of mulberry grafting were not known in Slovenia at least until the end of the eighteenth century. The grafting of high-yielding varieties was more common in the warmer regions of Italy.



At the beginning of the nineteenth century, significant attempts in mulberry cultivation and selection were made by the Sericulture Station of Gorizia. The Gorizia Station was favoured by its direct connection to the Venetian sericulture. The rapid increase in the production of silk in Gorizia caused them to be serious competitors to the Viennese sericulture. Gorizia's sericulture prospered, due to its natural advantages, although the companies did not benefit from loans, as did the Viennese ones.

When the Schools for Viticulture and Fruit Cultivation in Klosterneuburg and Maribor were established in the mid-nineteenth century, sericulture was taught both in theory and practice. Furthermore, in the middle of the nineteenth century, the Styrian Sericultural Society was founded, which provided practical courses for farmers. Furthermore, the society established a large mulberry nursery in Graz and began to supply Lower Styria and Carniola with lots of mulberry trees.

The history of mulberry cultivation and selection in Lower Styria is intricately connected with the fascinating agricultural rise in production of horticultural plants of the Novo Celje mansion, known as Styrian Eden, which was significantly promoted by Archduke John of Meran (1782–1859, brother to the Austro-Hungarian emperor Francis II). In 1843, the owner embarked on a remarkable endeavour by planting an initial 13,000 mulberry trees at the Plevna mansion. The favourable conditions and robust growth of the existing plantations prompted the addition of another 10,000 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 comprised ten large plantations, with five adhering to the Italian model. Notably, all medium- and high- cutting forms of Italian mulberry trees were grafted above the root crown, demonstrating advanced horticultural techniques. These trees were mainly of the 'Giazzola' variety, followed by 'Filippine' variety, renowned, at that time, for their exceptional leaf yield and quality (Zimmermann, 2016). The Venetian-style plantations known as 'La Piantata Veneta' were thoughtfully arranged to ensure protection from winds and ample sunlight. Straight rows featured alternating mulberry trees in semi-low and high cutting form, accompanied by high-quality vine varieties, including ‘Burgundian’ and ‘Moselle’ (Figure 1, Figure 2). This systematic approach ensured a balance between high and semi-low formed trees and a harmonious integration of vines .

The success of Novo Celje's sericulture project was highlighted by the expert Antonio de Marco Paolino, who marvelled at the lush growth and bright foliage of the mulberry trees and vines. He attributed this success to the favourable location, thorough tillage, generous fertilization, the quality of trees, and protective measures against harsh winters.

Figures: The Plevna mansion surrounded by a Venetian-style mulberry–vine planting system (“La Piantata Veneta”) in mid-19th century (Zimmermann, 2016). 2) Scheme of mulberry plantation design and tree arrangement at the Novo Celje mansion in mid-19th century (Zimmermann, 2016). 3) Second season (2016) of mulberry planting at the UM collection, including local varieties inventoried across different Slovenian regions. 4) Student-assisted work in the collection in season 2018.

In the spring of 1845, Novo Celje expanded their plantations to the Turnišče mansion at Ptuj, by importing 2,000 mulberry trees from Rome using Perinell's method. The plantation at the Turnišče mansion, thereby, signified a continued commitment to the further development of sericulture.

In 1896, Ivan Bolle's book ‘Teachings about moriculture (Murvoreja)’ provided valuable insights into mulberry cultivation in Slovenia. Since in the 19th century the rural population was predominant, arable land was of great importance; therefore, the mulberry represented a valuable advantage for farmers, due to its adaptability to peripheral areas, roadsides, field edges and less fertile areas. Bolle recommended planting mulberries in 1.3-meter-wide pits and taking soil quality into account. Fertilisers were utilized to promote robust growth.

The need for grafting arose due to the limitations of wild mulberries, which had small and lobed leaves less suitable for silkworms as they matured. Unfortunately, specific variety names were lost in history, and only the most silkworm-friendly varieties prevailed (Bolle, 1896). Mulberries were pruned in a manner similar to the Friulian approach, creating a multi-branched vase pruning shape that allowed light and air to penetrate, and made it easier to collect the leaves. The three-year pruning process aimed at obtaining a uniform branch size, a horizontal crown, and maximum leaf production with fewer fruits. Pruning also promoted the accelerated growth and sustainability of the trees. The primary goals of pruning were to maintain a horizontal canopy, prioritise high-quality foliage over fruit production, and promote tree growth and longevity.

Sericulture and the cultivation of mulberry trees experienced a significant decline after World War II, with no sericultural activities practiced for 70 years. Historical collections from the Sericulture Station of Gorizia, the plantations of Novo Celje, Plevno and Turnišče did not survive this period. The revival of sericulture began with the joint Hungarian-Slovenian Research Project (N1-0041) in 2015 and the establishment of a mulberry germplasm collection at the Faculty of Agriculture and Life Sciences, University of Maribor. This research institution, tracing its roots back to the School of Viticulture founded by Archduke John in 1822, had incorporated sericulture into its curriculum since 1870, aiming to integrate sericultural theory and practice into the study programme. Initially located in the town centre, the original school site was later repurposed by the agricultural institute, with its garden being replaced by fruit trees.

The mulberry germplasm collection at the University of Maribor was established in 2015 and spans 0.6 hectares. It is divided into three main sections. The first section maintains traditional sericultural mulberry varieties sourced from the germplasm collections of the Sericulture Laboratory CREA Padua and SCS Vratsa, including varieties such as ‘Florio’, ‘Morettiana’, ‘Kokusou 20’, ‘Kokusou 21’, ‘Kokusou 60’, ‘Giazzola’, ‘Muki’, ‘Restelli’, ‘Kiuryu’, and ‘No 25’. The second section comprises vegetatively-propagated trees from local historical Slovenian and Hungarian specimens, collected during a detailed inventory of the mulberry gene pool from 2015 to 2018 as part of the joint research project. This effort aimed to reconstruct and preserve the genetic heritage of ancient mulberry trees, by selection of local varieties optimally adapted to the region's pedoclimatic conditions and available to farmers. The third section of the collection focuses on species and hybrids primarily cultivated for fruit production, originally aimed at preserving varieties from all major *Morus* species suitable for the geographic region.

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MULBERRY SYSTEMATICS

Origin, systematics, key morphological traits, and conservation of mulberry varieties in relation to sericulture

Mulberries (*Morus* spp., Moraceae) are deciduous trees with a long history of domestication and selection for sericulture. In Europe, the earliest mulberry species introduced was *Morus nigra* L., native to western and southwestern Iran. *M. nigra* thrived in the Near East and Europe at least since the Iron Age and Roman times, as documented by literary sources and archaeobotanical records. This predates the widespread establishment of *M. alba* L., which was introduced from East Asia into the Mediterranean Basin with the expansion of sericulture, probably between the ninth and twelfth centuries. Thereafter, *M. alba* was gradually promoted in late Byzantine era and expanded markedly from the sixteenth century onward, reaching its golden era of cultivation during the eighteenth and nineteenth centuries, when sericulture flourished across most European countries. The widely distributed "Filippine" variety, taxonomically treated as *M. multicaulis* (*M. indica* var. *multicaulis*) and historically reported as imported via the Philippines, entered the European cultivation in the early nineteenth century (often cited around 1825) and is commonly placed within the *M. indica* genetic background. Additional high-leaf-yielding varieties associated with the *M. indica* complex, frequently referenced under traditional (variety-level) names such as *latifolia*, *kagayamae* and *bombycis*, were introduced from Japan between the 1930s and 1950s. In recent decades, hybrids involving *M. rubra* of the American origin have also been introduced to Europe, primarily for fruit production but in some cases also considered for sericultural use.

From a sericultural perspective, the most important genetic background is concentrated in the white mulberry (*Morus alba* sensu lato) and the Indian mulberry ingroup (*Morus indica* sensu lato), which together underpin most traditional and modern high-leaf-yield varieties. These ingroups are taxonomically and genetically complex because mulberries exhibit pronounced phenotypic plasticity (notably leaf heterophylly), variable sex expressing systems (monoecious or dioecious, including variations among genotypes) and extensive cytogenetic diversity (ploidy ranging from predominantly diploid and triploid cytotypes in *M. alba* to docosaploidy in *M. nigra*). Moreover, frequent spontaneous hybridisation as well as targed genetic recombination through breeding programmes blurred boundaries among species and on lower taxonomical level. Historically, mulberries were often propagated generatively (by seeds), which increased genetic variation as well as within-region diversity. In warmer regions of Italy and the former Austro-Hungarian monarchy, grafting of high-performing genotypes has been more common since late 18th century.

Consequently, morpho-phenological traits alone are frequently insufficient for reliable cultivar identification, even when detailed morphological descriptors are applied. Moreover, this biological and taxonomic complexity directly affects how genetic resources should be conserved, how planting material is maintained and propagated, and how mulberry breeders and growers select genotypes suited to local climate and management conditions. In response, best practice increasingly combines standardised morphological cataloguing supported with molecular tools to resolve uncertainties at lower taxonomic level, identify synonyms, and support robust selection and conservation decisions.

A specific challenge for the taxonomic positioning of the mulberries presented in the ARACNE mulberry catalogue is that many varieties are recorded under traditional names and synonyms (syn.) that have been applied historically to taxa now treated under different accepted scientific names and taxonomical level. In addition, many modern sericultural varieties originate from simple or complex crosses (spontaneous and/or artificial breeding) among *M. alba*, *M. indica* and *M. rubra*. Accordingly, most varieties associated with *M. alba* and *M. indica* are treated as sensu lato (s.l.; "in the broad sense"), whereas putative *M. rubra* accessions are provisionally assigned as *M. rubra* confer (cf.). The qualifier "cf." indicates that most diagnostic characters correspond to *M. rubra*, but some are ambiguous; identification is therefore provisional and expected to be resolved through comparison with reference material. The genetic relationships of the catalogued varieties are currently being analysed within the ARACNE project.

Morus alba L. (white mulberry): the global sericultural backbone

Origin and distribution. *Morus alba* is accepted as native to the Central China and has been disseminated widely through centuries of sericulture, becoming extensively cultivated and often naturalised across Europe and many other regions. This long history has generated a large pool of local varieties and named cultivars, including centuries-old trees that represent both cultural heritage and locally adapted genetic resources.

Key morphological traits relevant to sericulture. *M. alba* is typically a fast-growing small to medium-sized tree with highly variable leaves, that are commonly ovate to broadly ovate, predominated by retuse and truncate leaf base, obtuse and acute leaf apex, acuminate tip and crenate or serrate leaf margins. Heterophylly is common (lobed and unlobed leaves may occur on the same individual), with number of lobes influenced by genotype, tree age and vigour, pruning, and position within individual branch and within canopy. Buds are usually broadly to narrowly triangular and greyish to medium brown; current-year shoots are predominantly greyish to medium brown. Sexual expression varies (monoecious or dioecious), and inflorescences form male and/or female catkins, including polygamous expressions depending on genotype. Infructescences (soroses) show wide colour variation, ranging from yellowish-white to pink, dark red and black, with intermediate shades during ripening.

Conservation value and potential. Sericultural selection has historically favoured genotypes with high leaf biomass and suitable leaf texture, because leaf quantity and quality directly influence silkworm performance. Conserving *M. alba* diversity is therefore essential to sustaining sericulture under changing climates and management systems. *Ex-situ* field collections are essential for maintaining cultivars; however, long-term security increasingly requires complementary backup strategies (e.g., cryopreservation of dormant buds) and systematic documentation to reduce genetic erosion and loss of historic local varieties.

Morus indica L. (Indian mulberry): a high-yield sericultural source in breeding programmes

Origin and distribution. *Morus indica* is of particular relevance, because many key sericultural cultivars are related to this taxon. It originates from India, with many indigenous and monumental trees associated with the Himalayan region, where it occurs along mountain slopes and valleys up to approximately 2,200 m a.s.l. across the Himalayan belt. The species is now introduced in Asia, Africa, Southern Europe and the United States.

Key morphological traits relevant to sericulture. In sericultural practice, *M. indica* is commonly associated with vigorous growth and large leaves and has contributed substantially to leaf yield and biomass traits through selection and hybridisation. Its morphological expression is strongly influenced by environment and management; therefore, cultivar-level identification based on leaf and phenology alone remains unreliable. Traditional variety-level names frequently associated with the *M. indica* complex include *bombycis*, *latifolia*, *kagayamae* and *multicaulis*, although their morphological delimitation and taxonomic treatments remain inconsistent among researchers. Leaves often show retuse to cordate bases, obtuse to acute apices with acuminate and frequently caudate tips, and margins ranging from serrate and biserrate to dentate. Buds are generally long and narrowly triangular, light grey to dark brown. Current-year shoots often appear in greenish to yellowish-brown colours. Infructescences are typically cylindrical, frequently asymmetric, reddish-black to black at maturity, with persistent stigmas.

Conservation value and potential. *M. indica* germplasm is valuable for maintaining and improving productivity across diverse environments. In Europe, it is represented mainly by introduced material conserved in germplasm collections, where it can contribute to resilient sericultural systems by widening the genetic base for the breeding process (hybridisation and selection). Variety identification is critical, as without genetic verification, accessions may be mislabelled, duplicated under different names, or unintentionally hybridised.

Morus nigra L. (black mulberry):
Ancient species revered by Greeks and Romans

Origin and distribution. *Morus nigra* is accepted as native to western and southwestern Iran and has been cultivated for a very long time across numerous geographical areas, including parts of Europe, primarily for fruit and cultural value.

Key morphological traits relevant to sericulture. *M. nigra* can generally be separated from *M. alba* in the field by several vegetative characters. 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 inflorescence are generally unisexual catkins. The juicy fruits (soroses) are spherical, 1-3 cm long, greenish when unripe, gradually turning red and later dark black, and are very aromatic when fully ripe. This species is also characterised by extreme cytogenetic distinctiveness, e.g. very high chromosome number associated with polyploidy.

Conservation value and potential. Although *Morus nigra* was the first mulberry species associated with the establishment of sericulture in Europe and was later progressively replaced by *M. alba*, it is not considered a primary sericultural species today. One of the reasons for its more limited distribution is that the species is difficult to propagate by cuttings and grafting. Nevertheless, *M. nigra* remains a key component of Europe's mulberry cultural landscape and is increasingly threatened by severe genetic erosion. Therefore, conserving *M. nigra* trees is of high priority.

Morus rubra L. (red mulberry): North American origin and European introduction with hybridisation implications

Origin and distribution. *Morus rubra* is accepted as native to southeastern Canada through the central and eastern United States and has been introduced elsewhere, with local occurrences outside its native range.

Key morphological traits relevant to sericulture. *M. rubra* is usually a small to medium-sized tree with leaves variable in shape and frequently unlobed to lobed. The adaxial lamina surface is relatively rough, with deep venation, whereas the abaxial surface may show variable pubescence. A key practical issue is its ability to hybridise with introduced *M. alba*, which complicates conservation and identification in areas where both species co-occur and reinforces the need for molecular verification when evaluating accessions.

Conservation value and potential. In Europe, *M. rubra* is an introduced species mainly valued for fruit. Its sericultural importance is generally secondary to *M. alba* and *M. indica*. Conservation strategies that include *M. rubra* should explicitly manage the risk of untracked hybridisation and ensure accurate identity assignment.

Conservation opportunities for sericultural use: why integrated characterisation is decisive

The mulberry genetic resources used in sericulture are predominantly clonal and maintained in *ex situ* germplasm collections, *in situ*/on-farm heritage trees, or as scattered and sometimes abandoned trees within former sericultural landscapes. This makes them vulnerable to pests, diseases, extreme weather, and discontinuities in long-term management. For sericulture, the priority is to secure and rationally utilise genotypes combining high leaf yield with local adaptation, while safeguarding heritage varieties that embody long-term historical selection. This requires a conservation model that (i) maintains varieties in *ex situ* gene banks, (ii) strengthens long-term security through backup methods such as cryopreservation, and (iii) documents and protects *in situ*/on-farm heritage trees that remain poorly inventoried. The value of these actions is maximised only when the identity and relationships among accessions are clarified.

Current genetic characterisation focus and the role of the catalogue in building a robust identification key

A persistent limitation in mulberry research is that morphological descriptors alone cannot fully resolve cultivar identity, because key morphological traits (leaf size parameters, lobed or unlobed leaves, leaf base, apex, tip and margin type, along with phenology, and reproductive structure traits) vary within a genotype across environments and management practices. To address this, the genetic characterisation of varieties maintained in the germplasm collections CREA (Italy), SCS Vratsa (Bulgaria), UM (University of Maribor), and IMIDA (Spain) is currently being explored, with the catalogue serving as the reference source for the most informative morphological and yield-related traits.

These traits will be combined in multivariate analyses together with molecular markers (Simple Sequence Repeat Markers, SSR) to (1) verify accession identity, (2) detect synonymy, (3) reveal taxonomic structure within and among the *M. alba* s.l. and *M. indica* s.l. ingroups, and (4) support the development of a practical, high-value morphological identification key. The intended outcome is a supportive determination key usable for germplasm curators and mulberry growers, while being scientifically robust because it integrates selected morphological descriptor combinations validated against SSR-based genetic evidence. This approach directly strengthens conservation for sericultural use by enabling improved selection of locally adapted, high-leaf yield varieties, ensuring true-to-type propagation, and safeguarding the remaining heritage gene pool as a strategic resource for future sericultural needs.

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Aracne Mulberry Varieties' Catalogue

Advocating the role of Silk Art and Cultural Heritage at National and European scale.

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Collections

- CREA
- SCS VRATSA
- IMIDA
- UM

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METHODOLOGY

Identification and taxonomical evaluation of the germplasm resources

Based on the lists of mulberry varieties that has been provided by the Aracne partners within the first year of the project (D1.4 – Progress report on the collected mulberry samples, see Table 1 and Suppl. Tables I-IV), selected trees from CREA, SCS Vratsa, UM and IMIDA germplasm collections were included in the monitoring of morphological descriptors and silica dried leaf material was send to CREA for molecular analyses.
High yielding sericultural and local varieties from the following collections were included:

- **CREA Germplasm**: The evaluation included 57 varieties from diverse taxonomical and geographical origins (Italy, China, France, India, Japan).
- **Vratsa Germplasm**: A total of 70 mulberry varieties were evaluated. The selection focused on local Bulgarian varieties and those from Eastern Europe and Central Asia (Armenia, Azerbaijan, Georgia, Romania, Ukraine, and Uzbekistan) to trace the possible spread of mulberries (and sericultural activity) from the East to the West. These varieties, introduced and planted at the SCS-Vratsa germplasm between 1965 and 2004, offer a unique insight into regional diversity.
- **UM Germplasm**: 166 distinct varieties were included in the analyses, representing 132 local historical white mulberry (*M. alba* s.l.) trees inventoried in Slovenia (69) and in Hungary (63), along with 34 reference varieties used in sericulture and fruit processing. The varieties were planted mainly between years 2015-2018.
- **IMIDA germplasm**: 35 varieties varieties originating from Italy, Spain and Japan were included in the analysis.

The main issue was that most varieties are labelled with old traditional taxonomic names, synonyms (syn.), that apply to a taxon that now goes by a different scientific name. Moreover, most modern sericultural varieties originate from simple or complex spontaneous and/or artificial crosses between *M. alba*, *M. indica* and *M. rubra*. Therefore, most of the varieties belonging to *M. alba* and *M. indica* have been concurrently defined as sensu lato (s.l.), which means "in the broad sense", whereas *M. rubra* varieties have been concurrently asigned as confer (cf.). This qualifier indicates that most of the diagnostic characters correspond to *M. rubra*, but some characters are unclear. The identification is provisional but is likely to be definitive after comparing with reference material. Varieties that are noted as *M. rubra* cf. could originate from simple or complex spontaneous and/or artificial crosses involving *M. alba*. Their genetic relationship is going to be analysed under the scope of ARACNE mulberry research. The collections also include forms (f.) of *M. alba* (*M. alba* f. *pendula*, *M. alba* f. *pyramidalis*), which denote a taxonomic category bellow the species level and refer to specific morphological differences. Variety (var.) is a taxonomic category that ranks between the subspecies and forma level, its members differing from others in minor but permanent or heritable characteristics.

According to the currently accepted classification, the varieties identified, evaluated, and sampled in the germplasm were taxonomically organised as shown in Table 1, taking known synonyms into account.

Table 1 - Current taxonomical status of *M. alba* s.l., *M. indica* s.l. and *M. rubra* cf. along with synonyms.

Current taxonomical status	**synonyms**
M. alba s.l.	*M. atropurpurea*, *M. alba* var. *atropurpurea*
M. alba f. *pendula*	*M. pendula*
M. alba f. *pyramidalis*	*M. pyramidalis*
M. indica	*M. australis* *M. bombycis* *M. kagayamae* *M. latifolia* *M. multicaulis*, *M. indica* var. *multicaulis* *M. planifolia*, *M. multicaulis* var. *planifolia* *M. rotundiloba*

Current taxonomical status	synonyms
M. rubra cf.	Varieties that are noted as *M. rubra* cf. could originate from simple or complex spontaneous and/or artificial crosses involving *M. alba*. Their genetic relationship is going to be analysed under the scope of ARACNE mulberry research.

Methodology for maintenance of mulberry accessions

Conservation of mulberry accessions begins with their collection, multiplication, and subsequent establishment in *ex-situ* conservation sites. Different maintenance practices are essential to this process, including propagation methods, pruning techniques, and fertilisation strategies. The upcoming chapters will detail the maintenance methodologies employed by the germplasm collections of CREA, SCS Vratsa, and UM. These institutions serve as foundational models for other partners, providing a backbone for the effective conservation and maintainance of mulberry collections.

Methodology for mulberry germplasm characterisation and evaluation

Morphological traits of mulberry accessions maintained in the ARACNE partners' collections (CREA, Vratsa, IMIDA, UM) were analyzed using **UPOV Mulberry descriptors**, basically modified according to the **Guidance model to collect mulberry samples**. To standardise the database of morphological descriptors across all partners, a template for an Excel file pivot table was developed. This template has been utilized by CREA, SCS Vratsa, IMIDA, and UM to ensure consistency in data recording and analysis. The list of descriptors is summarized in Table 2.

Table 2 - The list of mulberry descriptors employed for the evaluation of the mulberry genetic resources maintained in the germplasm collections of ARACNE partners.

Category	Descriptor	Options
Taxonomical and basic information	Identification/ Accession n.	Data entry
	Species	*M. alba, M. indica, M. cathayana, M. celtidifolia, M. insignis, M. kordesiana, M. loboensis, M. macroura, M. mesozygia, M. microphylla, M. miyabeana, M. nigra, M. notabilis, M. rubra, M. serrata, M. trilobata, M. wittiorum,* interspecific hybrid
	Varietal name	Data entry
	Date of sampling	Data entry
	Date of sampling	Data entry
	Number of individuals in the repository	Individual, Mulberry plantation, Mulberry row
	Method of observation	Single measurement of a group of plants or part of plants, Measurement of a number of individual plants or parts of plants, Visual assessment by a single observation of group of plants or part of plants, Visual assessment by observation of individual plants
	Mode of origin/biological status	Natural, Traditional cultivar/landrace, Advanced or improved cultivar, Hybrid
	Ploidy level (if known)	Haploid, Diploid, Triploid, Tetraploid, Hexaploid, Docosaploid, Polyploid, Ploidy level not yet determined
	Geographical origin lat.	Data entry

Category	Descriptor	Options
	Geographical origin long.	Data entry
	Availability	Public, Street, Square, Private Garden, Botanical Garden or Gene bank, Agricultural landscape
	Areas of cultivation	Temperate, tropical, sub-tropical
Morphological characteristics	Trunk circumference (cm)	<180 cm, 180-249 cm, 250-299 cm, >300 cm
	Exact measurement of trunk circumference (cm)	Data entry
	Tree growth habit	Upright, Semi-upright, Weeping
	Tree vigour	Bad condition, Good condition
	Pruning practices	Unpruned tree, Frequently pruned, Yearly pruned tree
Trunk	Trunk colour	Greyish brown, Light brownish-grey, Reddish brown
	Trunk irregularities/damage	Curved, Hollow (pipe tree), Longitudinally cracked, External split
Shoots	Current years shoots: length (cm)	Data entry
	Current years shoot: number of lateral shoots	Data entry
	Current years shoot: length of internode	Data entry
	Colour of one-year old shoot	Greyish brown, Greenish brown, Yellowish brown, Medium brown, Reddish brown, Dark brown
	Lenticel density	High, Medium, Sparse
	Lenticel shape	Elliptical, Oval, Round
Buds	Bud shape	Broad triangular, Medium triangular, Narrow triangular, Ovate
	Bud colour	Greyish brown, Yellowish brown, Reddish brown, Medium brown, Dark brown
	Bud size	Small, medium, large
Leaves	Phyllotaxis	Alternate spiral, Alternate distichous, Opposite decussate
	Leaf shape	Simple, Lobed
	Peduncle length (cm)	Data entry
	Average leaf size: length (cm)	Data entry
	Average leaf size: width (cm)	Data entry
	Average leaf size: area (cm2)	Data entry
	Leaf blade	Low (<1.2 broad leaves), Medium (1.3-1.5), High (>1.6 long)
	Petiole range	Absent or very short (< 10 mm), Short (11-20 mm), Medium (21-40mm), Long (41-70 mm), Very long (>71 mm)
	Petiole size (cm)	Data entry
	Shape of leaf base	Cuneate, Truncate, Retuse, Cordate
	Shape of leaf apex	Acute, Obtuse, Obcordate
	Leaf blade tip	Absent, Caudate, Acuminate
	Leaf blade margin	Repand, Crenate, Dentate, Serrulate, Biserrate, Serrate, Aristate
	Hairiness	Glabrous, Midrib and veins, Evenly pubescent
	Glossiness	Glossy, Matte
Phenological descriptors	Date of swollen bud (week)	Data entry
	Date of bud burst (week)	Data entry

Category	Descriptor	Options
	Flowering date (week)	Data entry
	Date of first leaf (week)	Data entry
	Date of first leaf (week)	Data entry
	Early yellowing due to disease (week)	Data entry
	Abundant autumn colouring (week)	Data entry
	Leaf fall (week)	Data entry
	Time of infructescence ripening	Early, Early to medium, Medium, Medium to late, Late
	Uniformity of infructescence ripening	Early, Early to medium, Medium, Medium to late, Late
Reproductive structures	Sexual dimorphism	Monoecious, Dioecious
	Inflorescence type	Male, Female, Predominantly female with some male flowers at the base, Predominantly male with some female flowers at the apex, Predominantly male with some female flowers at the base, Predominantly female with some male flowers at the apex
Inflorescence size	Female inflorescence length (mm)	Data entry
	Female inflorescence diameter (mm)	Data entry
	Female inflorescence stalk length (mm)	Data entry
	Male inflorescence length (mm)	Data entry
	Male inflorescence length (mm)	Data entry
	Male inflorescence stalk length (mm)	Data entry
	Polygamous inflor. length (mm)	Data entry
	Polygamous inflor. diameter (mm)	Data entry
	Polygamous inflor. diameter (mm)	Data entry
Infructescence	Fruit weight (g)	Data entry
	Length (mm)	Data entry
	Width (mm)	Data entry
	Length of peduncle	Short, Medium, Long
	Colour	Yellowish white, Light pink, Purple brown, Reddish black, Black
	Taste	Acidic, Sweet, Balanced
	Infructescence shape	Ovoid/globose, Ellipsoid, Cylindrical, Irregular
Growth and yield attributes	Growth	Slow, Medium, Fast
	Length of primary branch (cm)	Data entry
	Internodal distance (cm)	Data entry
	Leaf No./meter	Data entry
	Weight of 100 fresh leaves (g)	Data entry
Chemical composition of leaves	Total protein (g/100 g)	Data entry
	Mineral (g/100 g)	Data entry
	Fibre (g/100 g)	Data entry
Response to different physological conditions	Response to drought	Resistant, Tolerant, Susceptible
	Response to salinity	Resistant, Tolerant, Susceptible
	Response to chilling stress	Good, Medium, Poor
	Response to repeated pruning	Good, Medium, Poor
Diseases and pests	Disease option	Fungal leaf spot, Bacterial leaf spot (*Pseudomonas syringae* pv. mori), Soft rot (*Pectobacterium carotovorum*), Ringspot virus
	Pest option	Mulberry moth (*Hyphantria cunea*), Thrips (5 species), Mites (*Tetranychus*

Category	Descriptor	Options
		sp.), Scale insects (Hemiptera), Mealy bugs (*Maconellicoccus hirsutus*), Red scale (*Aonidella aurantii*), Hairy caterpillar (*Spilarctia obliqua*), Jassids (*Empoasca Flavescens*)
	Any other disease or pest	Data entry
	Leaf necrotic spots	Low, medium, frequent
	Bark lesions	Frequent, Few
Additional remarks	Optional	Data entry

For the evaluation of morphological descriptors, varieties were meticulously selected from each germplasm collection to ensure a comprehensive and comparable analysis. The main morphological features were studied during the years 2023-2025. Supporting schematic and pictorial information of the studied descriptors are shown in Figure 1-5.

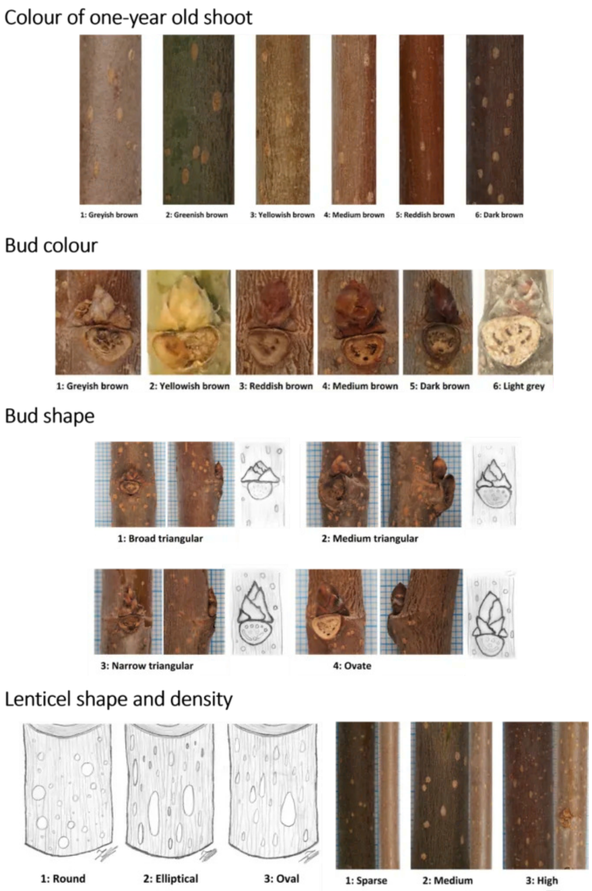

Figure 1: Morphological characterization of the one-year old shoots and buds. A) Colour of the one year old shoot, B) Bud colour, C) bud shape, D) Lenticel shape.

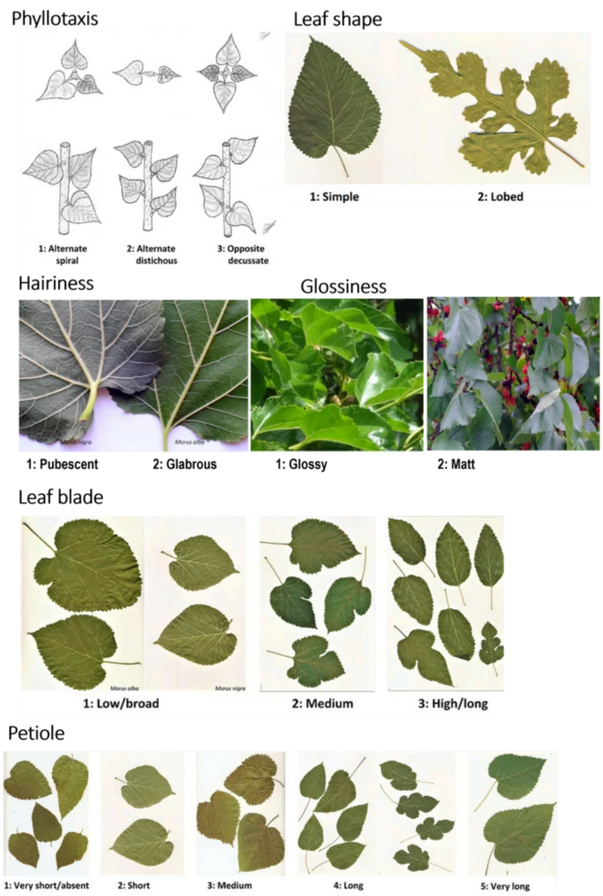

Figure 2: Morphological characterization of the leaves. Phyllotaxis, leaf shape, hairiness, glossiness, leaf blade, petiole.

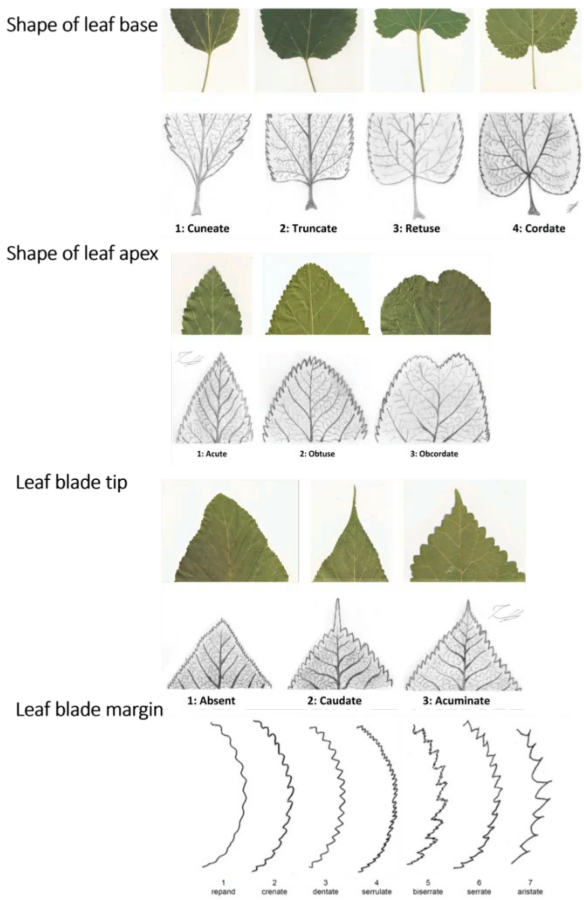

Figure 3: Morphological characterization of the leaves. Shape of leaf base, shape of leaf apex, leaf blade tip, leaf blade margin.

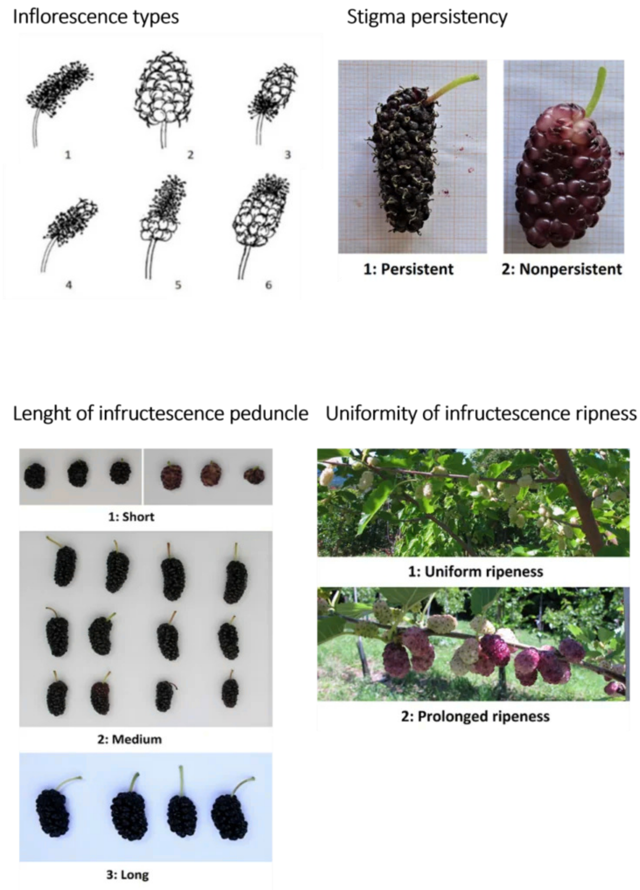

Figure 4: Morphological characterization of the reproductive structures. Inflorescence types, stigma persistency length of infructescence peduncle, uniformity of infructescence ripness.

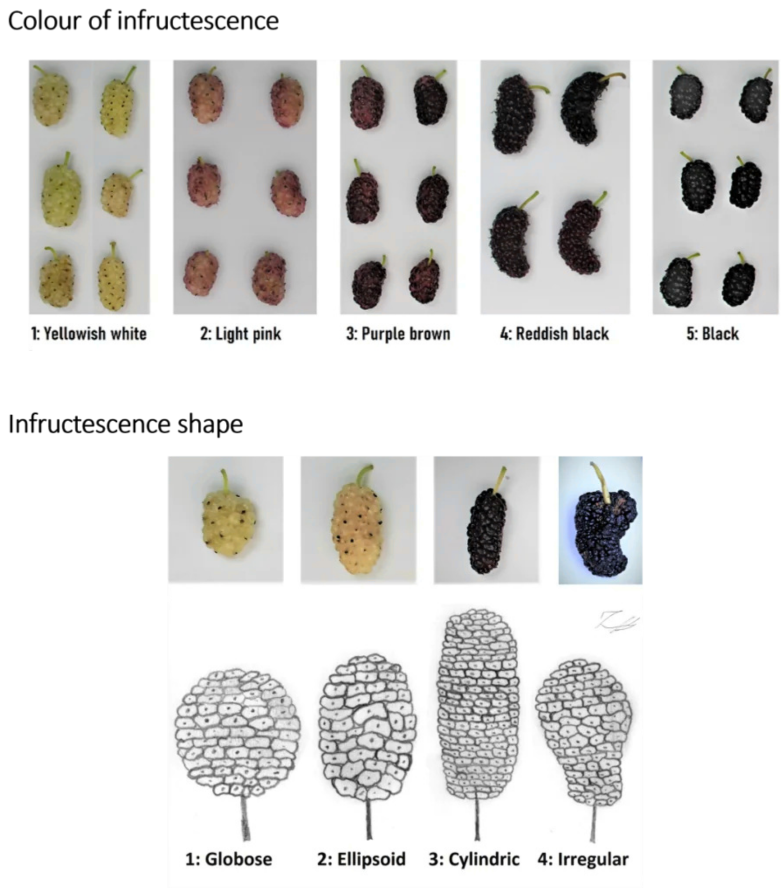

Figure 5: Morphological characterization of the reproductive structures. Colour of infructescence, infructescence shape.

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RESULTS

Results on characterisation of mulberry genetic resources

In the Deliverable **ARACNE_D1.4-Report-on-the-collected-mulberry-samples**, we present a comprehensive evaluation of vegetative and reproductive traits using standard mulberry descriptors, for the CREA, Vratsa, IMIDA and UM mulberry germplasm collections. Leaf descriptors and phenological evaluations were documented by the institutions during the first year of the ARACNE project. The evaluations conducted in 2024 and in vegetation season 2025 focused on other descriptors, specifically trunk, shoot, and bud characteristics, together with a detailed assessment of reproductive structures (inflorescences and infructescences). These data provide deeper insight into the diversity of morphotypes within the collections. In parallel, phenological monitoring was carried out in the second year and continuous in the third year of the project to observe and record seasonal changes and developmental stages of the trees, offering a foundational understanding of their growth cycles and reproductive patterns. This extended observation period enables the calculation of multi-year averages and the application of advanced statistical analyses, providing a more robust understanding of the data. It also supports the identification of the most informative vegetative and reproductive traits and the definition of distinct morphotypes which, together with genetic analyses, will guide future research and conservation strategies.

In the final year of the ARACNE project, these efforts are currently culminating in cataloguing and characterizing the morphological and genetic diversity present across the participating countries, reinforcing the project's commitment to preserving and enhancing European mulberry genetic resources.

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Imprint

Title: **Catalogue of Mulberry Varieties, Developed under the Recreation of European Mulberry Heritage**

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ARACNE partners involved in the Mulberry descriptor monitoring

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