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REVIEW ARTICLE

ORIGIN, TAXONOMY, BOTANICAL DESCRIPTION, GENETIC DIVERSITY AND BREEDING OF MULBERRY

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ABSTRACT

Mulberry belongs to the family Moraceae, tribe Moreae, genus *Morus* and species *Morus alba* L. - white mulberry. Mulberry genus Morus grown as a perennial tree or shrub is an economically important plant used for Sericulture and it is the sole food plant for the domesticated Silkworm *Bombyx mori* L. Due to the presence of attractant, biting factor and swallowing factors, Silkworm is attracted towards mulberry. *Morus* which is widely distributed in Asia, Europe, North and South America and Africa is cultivated exclusively in East, Central and South Asia for silk production. People of Karnataka, Andhra Pradesh, North Eastern states and other parts of India much depend on Sericulture activities where only mulberry and its varieties are grown for the purpose of Silkworm rearing. In India, the genus *Morus* is represented by four species *viz., M. indica, M. alba, M. serrata* and *M. Laevigata.* The natural distribution of the genus has considerably changed because of its extensive cultivation for silkworm rearing. There are more than 70 countries which produce silk, among which China, India, Vietnam, Uzbekistan, Brazil, Thailand, and Bangladesh are the leaders. Mulberry leaves are also used as animal fodder and the fruits are used for making various confectionery products such as jam, marmalade, pulp and paste. Although, the maximum utilization of mulberry is in Asia, this does not mean that mulberry is restricted only to Asian countries. Mulberry is present on almost all continents and is used for various purposes, including its ornamental value in gardening and landscaping. Although, more than 68 species have been widely recognized, the taxonomy of mulberry is still a matter of great dispute and intense research due to the high rate of natural hybridization among the species. Hence, a large number of the so-called species are hybrids and their true taxonomic identity is difficult to deduce properly. To complicate things further, different ploidy levels ranging from diploids with 28 chromosomes to docosaploid with 308 chromosomes are very common among most species. Out of these 68 species, only a few, mostly belonging to white mulberry (*Morus alba*), are used for sericulture while a few other species such as red mulberry (*Morus rubra*) and black mulberry (*Morus nigra*) are used for fruits. Silk production still is a large, profitable industry for several countries, notably Italy, Turkey, India, and China. Indeed, mulberry production cannot be extricated from silk production and trade—silkworms feast on mulberry leaves. The tree's introduction to other nations invariably stemmed from the country's desire to produce its own silk garments, rather than pay for expensive imports. Even the Virginian colonists attempted to cultivate the trees as early as 1623. Though their efforts failed, the colonists opted to sell tobacco to Europeans in exchange for silk. Initially, India imported much of its silk from China, as evident by its earliest name, "Chinsukh." Assam produced a type of wild silk, although these worms thrived on castor leaves. The ancient treatise, Arthashastra (a publication likely produced between the 7th century BC and 2nd century BC) mentions Assam's bourgeoning silk trade. By the Ahom period (1223-1819), India's silk industry was thriving. The country's current mulberry silk production is largely concentrated in the south. In this review article on Origin, Taxonomy, Botanical Description, Genetic Diversity, and Breeding of Mulberry are discussed.

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INTRODUCTION

Mulberry belongs to the family Moraceae, tribe Moreae, genus *Morus* and species *Morus alba* L. - white mulberry (Wikipedia, 2024; Wikipedia, 2024b; USDA, 2024). Common names are white mulberry, russian mulberry, silkworm mulberry (Heuzé *et al*., 2019). In India, the genus *Morus* is represented by four species *viz., M. indica, M. alba, M. serrata* and *M. Laevigata.* The natural

distribution of the genus has considerably changed because of its extensive cultivation for silkworm rearing (Tikader *et al*., 2002). In India the genus *Morus* is represented by four species *viz.*, *M. Indica, M. Alba, M. Serrata* and *M. laevigata*. The origin the genus Morus is in China-Japan which includes East China, Koea and Japan. There are about 68 species recognised in the genus (Tikader *et al.,* 2002). Presently there are about 1300 gene banks in the World and maintaining about 6 million germplasm accessions. Among the sericultural countries , China is holding 2600 accessions, followed by Japan 1375, India 1053, Koea 615, and Bulgaria 140 in the *ex situ* field gene banks (Rao *et al.,* 2005). The centre of origin mulberry is China-Japan region. The center of diversity exists in the entire Himalayan belt where natural mulberry and their wild relatives exist in abundance (Rao *et al*., 2005). The loss of genetic diversity due to human activities has rawn the global attention for vegetational and floristic studies to develop biodiversity conservation programme in many countries including India (Rao *et al.,* 2005). Mulberry *(Morus* species) is out breeding and highly heterozygous perennial tree. Its high biomass production and protein rich foliage nurture the sericulture industry in India besides it is extensively used in agroforestry and horticulture programmes (Rao *et al*., 2005). Mulberry is abundantly available under natural habitat in the Himalayan belt and under managed habitats of on-farm conservation throughout the country (Rao *et al*., 2005). The genus *Morus* comprises about 68 recognized species. Presently there are about 1300 gene banks on agro biodiversity which are operating worldwide maintaining about 6 million germplasm accessions (Rao *et al*., 2005).

Exploitation of wild relatives of crop plants to a large extent depends on the efficient use of germplasm resources available in natural habitat and the centre of diversity. The primary objective for breeding is to identify the mulberry germplasm, which will be used as a parent. This includes the performance of individual accessions with regards to their origin, passport data, characterization, and evaluation through a series of tests in field (Tikader and Kamble, 2008). The crop improvement is the transfer of desired genes and gene combination from unadapted sources into most usable breeding materials. To bring greater diversity into the breeding pool, it requires introduction of exotic and wild materials. The breeders find it difficult to use unadapted materials from wild source. The intermediate materials produced after incorporating the new genes is treated as genetically enhanced materials, which may be useful to develop desired lines (Tikader and Kamble, 2008). Mulberry , a fast-growing deciduous woody tree of the family Moraceae, is grown widely in Asian countries for its leaves to feed the silkworm *Bombyx mori*, which feeds exclusively on mulberry leaves. Hence, mulberry is one of the most important components that decide the sustainability of this multi-billion dollar industry. There are more than 70 countries which produce silk, among which China, India, Vietnam, Uzbekistan, Brazil, Thailand, and Bangladesh are the leaders (Vijayan, 2011). Mulberry leaves are also used as animal fodder and the fruits are used for making various confectionery products such as jam, marmalade, pulp and paste. Although, the maximum utilization of mulberry is in Asia, this does not mean that mulberry is restricted only to Asian countries. Mulberry is present on almost all continents and is used for various purposes, including its ornamental value in gardening and landscaping (Vijayan, 2011). Although, more than 68 species have been widely recognized, the taxonomy of mulberry is still a matter of great dispute and intense research due to the high rate of natural hybridization among the species. Hence, a large number of the so-called species are hybrids and their true taxonomic identity is difficult to deduce properly (Vijayan, 2011). To complicate things further, different ploidy levels ranging from diploids with 28 chromosomes to docosaploid with 308 chromosomes are very common among most species (Vijayan, 2011). Out of these 68 species, only a few, mostly belonging to white mulberry (*Morus alba*), are used for sericulture while a few other species such as red mulberry (*Morus rubra*) and black mulberry (*Morus nigra*) are used for fruits (Vijayan, 2011).

Mulberry is an economically important tree being cultivated for its leaves to rear the silkworm *Bombyx mori*. Rearing of silkworm is an art and science popularly known as sericulture; an agrobased cottage industry provides employment to millions in China, India, Korea, Vietnam (Vijayan *et al*., 2012). Mulberry is a perennial tree that maintains high heterozygosity due to the outbreeding reproductive system. It is recalcitrant to most of the conventional breeding methods, yet considerable improvement has been made in leaf yield and leaf quality (Vijayan *et al.,* 2012). Conventional breeding in mulberry is a tedious, labour intensive and time taking process, which needs to be complemented with modern biotechnological methods to speed up the process (Vijayan *et al*., 2012). Sericulture is the science of rearing silkworms for the production of silk fibres. Sericulture is one of the major employment providers in India and several other Asian countries (Vijayan 2010). Commercially, four major types of silk fibres, namely mulberry silk produced by *Bombyx mori* L., tasar silk by *Anthereae mylitta* Drury, eri silk by *Samia cynthia ricini* and muga silk *Anthereae assamensis*, are used for textile purposes (Vijayan *et al*., 2012). India has the distinction of harbouring the silkworms of all these four types of silks, though the quantity of the silk produced varies significantly as the mulberry silk occupies a lion share of the total production (Vijayan *et al*., 2012).

Silk production was (and still is) a large, profitable industry for several countries, notably Italy, Turkey, India, and China. Indeed, mulberry production cannot be extricated from silk production and trade—silkworms feast on mulberry leaves. The tree's introduction to other nations invariably stemmed from the country's desire to produce its own silk garments, rather than pay for expensive imports. Even the Virginian colonists attempted to cultivate the trees as early as 1623. Though their efforts failed, the colonists opted to sell tobacco to Europeans in exchange for silk (Earth of India, 2013). Initially, India imported much of its silk from China, as evident by its earliest name, "Chinsukh." Assam produced a type of wild silk, although these worms thrived on castor leaves. The ancient treatise, Arthashastra (a publication likely produced between the 7th century BC and 2nd century BC) mentions Assam's bourgeoning silk trade. By the Ahom period (1223-1819), India's silk industry was thriving. The country's current mulberry silk production is largely concentrated in the south (Earth of India, 2013). Mulberry cultivation occurs in almost all of India's states. The primary grower of the fruit is Karnataka, as this state provides approximately 160,00 hectares for its growth. Distantly come Andhra Pradesh, Manipur, and West Bengal, respectively (Earth of India, 2013). The primary mulberry variant grown in India is *Morus indica.* This type thrives in warm, balmy weather, making it best suited to the south of India (Earth of India, 2013).

A second well-known mulberry type is *Morus alba,* also known as white mulberry. This north Indian fruit naturally thrives in Himachal Pradesh, Punjab, and Kashmir. White mulberries also grow in Maharashtra and Rajasthan (Earth of India, 2013). Another prominent mulberry variety is the Pakistan mulberry (*Morus serrata)*: this variant is relegated to Himachal Pradesh in the Himalayas, and in the sub-Himalayas at an elevation up to 3,300 meters. This unusual, caterpillar-like mulberry has made waves in the US, and it's sometimes found in California's trendiest farmers markets (Earth of India, 2013). A fourth type of common mulberry is the Himalayan mulberry (*Morus laevigata).* This type grows in Rajasthan, Maharashtra, West Bengal, Assam, and Manipur. These trees may live for at least a couple hundred years (Earth of India, 2013). The adage for most mulberry varieties is, "the darker, the better." The sweetest mulberries tend to be rich purple; almost black. Every part of the fruit should yield to the touch, and ideally, be a bit sticky. Of course, white mulberries live up to their namesake and remain white even at peak ripeness. Additionally, some white mulberries have been cross-pollinated with other varieties, and are thus pink or red. In these cases, going by touch is the better bet (Earth of India, 2013). The mulberry is an economically important crop, cultivated for its foliage to rear the silkworm *Bombyx mori* L. (Venkatesh *et al*., 2014).

The genetic diversity that exists in the local and traditional varieties of cultivated plants is being lost continuously due to the demands in agricultural cropping system. The new improved varieties are forever genetically homogenous and, therefore, are more vulnerable to pathogens and adverse conditions (Naik *et al.,* 2015). This has prompted plant breeders to look for new sources of variation that might be of use in plant breeding programmes. Many national and international organizations have stressed the need for the collection, conservation and use of wild relatives of cultivated plants (Naik *et al*., 2015). Wild populations found within the same agro-climatic environment as cultivated varieties offer an advantage as they are already adapted to those conditions. Their use in crop improvement programmes for novel traits and genes offers an exciting possibility for genetic improvement and sustainable agriculture (Naik *et al.,* 2015). Mulberry productivity is a crucial factor in sericulture economics as 60% of the total cost of production of cocoons goes to the production of mulberry leaves, which is the only feed for silkworm (*Bombyx mori* L.) (Naik *et al.,* 2015). The distribution of two wild mulberry species, *viz*., *Morus laevigata* and *M. serrata*, in the Indian subcontinent has been first reported by Hooker (Naik *et al.,* 2015). *M. laevigata* naturally occurs in the North-eastern states, West Bengal including Darjeeling district, Uttarakhand, Himachal Pradesh and Jammu and Kashmir (Naik *et al.,* 2015). Though the species is rarely used for late age rearing of silkworms, it is extensively used as animal fodder and its timber is highly valued. Large populations of wild *M. laevigata* have also been recorded in the Andaman Islands. Besides, the species has also been introduced for cultivation for its edible fruits in some places of Madhya Pradesh, Chhattisgarh, Jharkhand and Odisha (Naik *et al.,* 2015). In South India, isolated trees of the species are grown specifically for shade in coffee plantations of Yercaud in the Shevoroy hill range. The species has wider distribution from sub-Himalayan regions to coastal lines of Andaman Islands and exhibits great deal of phenotypic diversity and adaptability. In contrast, *M. serrata*, popularly known as 'Himalayan mulberry' (also called Kimu) is restricted to Himalayan hill slopes at altitudes ranging from 1500 to 2200 m in the states of Uttarakhand, Himachal Pradesh and Jammu and Kashmir. This species is seldom utilized for silkworm rearing due to undesirable leaf characteristics (Naik *et al.,* 2015).

It is well established fact that, in sericulture, more than 60% of total cost of cocoon production goes towards Mulberry production alone. Hence, in recent years maximum attention has been given for the improvement of mulberry both in terms of quality and quantity (Sharma *et al*., 2015). Nutritive value of mulberry (*Morus* spp.) leaf is a key factor besides environment and technology adoption for better silkworm cocoon crop. Among the various factors influencing silkworm growth, leaf quality plays a major role. It is a fact that leaf quality differs among mulberry varieties. Quality and quantity of mulberry leaves is highly influenced by varieties, cultivation practices, preservation techniques and age (Sharma *et al.,* 2015). Mulberry leaves containing more total sugar, protein and chlorophyll content are best relished by silk worm. Nutritive requirement of silkworm larvae vary with maturity of leaves. Experiment revealed that mulberry varieties C776, BC259, RFS175 among trees and Shiwalik, TR10, S1535 among bushes established its nutritional superiority with respect to total protein, sugar and chlorophyll content. S1, S146, BC259 varieties recorded comparatively higher values in respect of morphological characteristics therefore the verities C776, RFS175, BC259, S1 and S146 may be recommended for commercial silk worm rearing purpose at field level for better cocoon yield as well as for sustainable growth and development of sericulture industry (Sharma *et al.,* 2015).

The north western region of the country represents highly variable agro-climate and cradles diverse mulberry genetic resources. The mulberry varieties on which the sustenance of sericulture in Jammu and Kashmir exist include local forms namely Chattatul, Brantul, Botatul, Krehantul, Janglitul, Kablitul, Chattatul (Mirgund), Chattatul (Zaingeer), Lajward, Nadigam, Hauntul etc. However, Chattatul belonging to *M. alba*, is one of the important local mulberry varieties grown throughout Kashmir. Four mulberry species namely *M. indica*, *M. alba*, *M. laevigata* and *M. serrata* are found in India and all the four species are available in Jammu and Kashmir (Shabnam *et al.,* 2016). Similarly sub-tropical sericulture zone in Jammu and Kashmir is also sustaining on the local mulberry varieties. The local mulberry wealth predominantly comprises the variety *Sujanpur local* belonging to *M. indica* is utilized mainly for silkworm rearing and to a lesser extent wild variety *Kumai* is utilized especially for late instar stages (Shabnam *et al.,* 2016). The horizontal expansion of sericulture in traditional and non-traditional states has made it necessary to develop mulberry varieties specific to various agro-climatic zones. At present various improved varieties in use are mostly developed, involving exotic accessions as parents (Kala *et al*., 2016). An understanding of genetic diversity is must for selection of parental lines to gain vigor in hybrid. In the present study, an initiative was taken to assess the genetic diversity among mulberry (*Morus alba)* genotypes using morphological and PCR based molecular markers (Kala *et al.,* 2016). The North Western region of India which includes Jammu and Kashmir represents highly variable agro-climatic conditions and cradles diverse mulberry genetic resources. Lot of diversity in the mulberry wealth exists in this region which could be utilized to broaden its genetic base. It is estimated that about 25% of the available 150 lakh mulberry trees in J & K comprise the local/wild genotypes (Shabnam *et al.,* 2016).

There are 4 indigenous species of mulberry *viz Morus indica, M. alba, M. laevigata and M. serrata*. Jammu and Kashmir State has the privilege of possessing all the four indigenous species of mulberry. Because of its adaptability to cross pollination with no inter-specific reproductive barriers a vast range of diversity in the genetic stocks has crept in thereby rendering it highly heterozygous plant species as a result every plant being different from other in natural population (Shabnam *et al.,* 2016). A total number of 1269 mulberry accessions are available in Central Sericultural Germplasm Resource Centre (CSGRC), Hosur, Tamil Nadu out of which only 3.23% collections are from Jammu and Kashmir. The available genetic wealth needs to be exploited by the mulberry breeders for aiming both as direct utilization and siphoning of the specific traits for further breeding programmes (Shabnam *et al*., 2016).

Mulberry of Moraceae family is regarded as a unique plant on this earth due to its broader geological distribution across the continents; ability to be cultivated in different forms; multiple uses of leaf foliage and its positive impact in environmental safety approaches such as ecorestoration of degraded lands, bioremediation of polluted sites, conservation of water, prevention of soil erosion and improvement of air quality by carbon sequestering (Rohela *et al.,* 2020). Mulberry is also used as a medicinal plant in improving and enhancing the life of human beings by utilizing the biologically active pharmacokinetic compounds found in leaf, stem and root parts (Rohela *et al.,* 2020). Further industrial exploitation of mulberry through preparation of various products in pharmaceutical, food, cosmetic and health care industries has gained the attention of industrialists. As mulberry is being exploited by sericulture, pharmaceutical, cosmetic, food and beverage industries along with its utilization in environmental safety approach; it is appropriate to call it as a most suitable plant for sustainable development (Rohela *et al.,* 2020).

Mulberry is a fast-growing deciduous and perennial tree or shrub in genus *Morus*. It is widely grown to feed the silkworm (*Bombyx mori* L.) in the sericulture industry as its leaves are natural and a single food for silkworm (Ipek *et al.,* 2021). Besides being a food for the silkworm, it has different usage areas, especially for consumption as a mulberry fruit (*M. alba* L., *M. laevigata* Wall., *M. nigra* L., *M. rubra* L.), which contain high phenolic acids and flavonoids for which it is processed in the fruit industry (Pekmez, Pestil, Köme, dried fruit, jam, jelly, marmalade, pulp, juice, paste, ice cream and wine) and in the production of high-quality musical instruments and furniture from the mulberry lumber (Ipek *et al*., 2021). n addition, mulberry plants have been used as a resource for medicines and drugs in Asian countries. Further it has some antioxidants and hypoglycaemic compounds (Ipek *et al.,* 2021). The Himalayan foothills are accepted as the source of the *Morus* spp. and later mulberries spread to the southern hemisphere. The major cultivation area for mulberry is the tropical region. Today, mulberries exist between 50° North and 10° South latitude to cover countries like Europe, Southeast Asia, Northeast Asia, Middle East, South Africa, and South and North America, including Mexico (Ipek *et al*., 2021). The genus of Morus shows high genetic diversity. The higher adaptation to different ecological conditions, easy natural hybridization and large genetic diversity make mulberry's genetic structure rather complicated and highly heterozygous. The high genetic heterozygous trait cause to classify mulberry as being very difficult. More than 150 species were cited in Kewensis Index but the description by Koidzumi is now widely accepted with 24 Morus species (Ipek *et al*., 2021).

Turkey produces the largest share of mulberry in the world. China leads the mulberry plantation in terms of area and has 6,26,000 hectares of area under mulberry cultivation, followed by India. Mulberries are cultivated for different purposes in different countries. Most of the countries grow mulberry plants for different purposes like production of silkworm. In countries like Europe, mulberry plants are mainly planted for its fruit. Some countries grow mulberries as fodder for silkworms and as sericulture-related materials while in Japan mulberry leaves are used for tea and powder juice (Hussain *et al.,* 2021). The species which are mainly cultivated for their leaves are *Morus laevigata*, *Morus rubra* and *Morus nigra* (Hussain *et al*., 2021). The total acreage of mulberry in India is around 282,244 hectares whereas total area under mulberry cultivation in Jammu & Kashmir is 4,717 hectares. In general, mulberry is mainly grown for its leaves, but few species of mulberry like *Morus alba*, *Morus indica*, *Morus* laevigata are also cultivated for their edible fruit (Hussain *et al.,* 2021). Till now 24 species has been identified in this genus and 100 varieties have been Known. However, only 19 species have commercial importance (Hussain *et al.,* 2021). In India, there are many species of *Morus,* of which *Morus alba, M. indica. M. serrata* and *M. laevigata* grow wild in the Himalayas (Hussain *et al*., 2021). Mulberries are categorized as Red (*Morus ruba*), Black (*Morus nigra*) and white (*Morus alba*) depending on the colour of fruit. Among all species, *M. alba* is the dominant one. White mulberry is named so as it remains white in colour even after ripening. Moreover, the fruit is bland and less sweet than other species. Most of the Indian varieties of mulberry belong to *M.indica* (Hussain *et al*., 2021). Mulberry is commonly consumed as fresh fruit or dried. Some fruit is processed into wine, fruit juice and jam due to its delicious taste, pleasing colour, low-calorie content and high nutrient content. Furthermore, mulberry fruit has long been used in the folk medicine for thousands of years, especially in China for treating sore throat, anaemia and tonsillitis (Hussain *et al*., 2021).

Mulberry is the sole food plant for mulberry silkworm (*Bombyx mori* L). It is a perennial, heterozygous, fast growing and hardy plant which is being cultivated in temperate, tropical and sub-tropical conditions across the globe. The improvement of its foliage productivity and quality could be achieved through the development of high yielding superior mulberry varieties via traditional breeding (Mogili *et al.,* 2023). The improvement of its foliage productivity and quality through breeding is the cheapest and most effective method that has direct bearing on cocoon production and in turn economy (Mogili *et al.,* 2023). Conventional breeding approaches have shown significant achievements in developing superior mulberry varieties with higher leaf yield, better leaf quality, wider adaptability, tolerance to low temperature, drought, soil alkalinity, salinity, resistance to diseases and pests in sericulture practicing countries like India, China, Japan, Thailand and Brazil (Mogili *et al*., 2023). The sustainability of sericulture depends not only on vertical development but also on the need of horizontal expansion in traditional and non-traditional areas with adverse climatic and soil conditions, and present climate change scenario (Mogili *et al.,* 2023). It has become imperative to develop mulberry varieties with wider adaptability, specific to various conditions prevailing in the chosen areas and resistant to

different diseases and pest, tolerant to low temperature, high temperature, drought, salinity, alkalinity (Mogili *et al*., 2023). Recently, there is a paradigm shift to multipurpose exploitation of mulberry for environmental safety, pharmaceutical, cosmetic, food and beverage industries. It is essential to bring greater variability into the gene pool of mulberry via introduction, and utilization of un-adapted and productive exotic and wild species (Mogili *et al.,* 2023). Further, integrated approaches utilizing advanced genomic tools including transgenic technology and marker-assisted selection in tandem with conventional breeding methods could be necessary toward genetic improvement of mulberry (Mogili *et al.,* 2023).

The mulberry which is important economically, is grown for its leaves, which are used to raise the silkworm *Bombyx mori* L. Mulberry leaves, especially those of the white mulberry, are crucial because they are the only source of food for *Bombyx* spp. Increased mulberry leaf production is required to boost sericulture productivity, and this can be accomplished by creating new varieties that produce more leaves while being more adaptable. It is crucial to have appropriate knowledge of the genetics and genomics of the plant in order to change the mulberry's genetic makeup, which enhances yield. In order to improve the sustainability and profitability of the silk industry in India, concentrated efforts will be made to merge conventional breeding with recent technological advancements (Manjunath *et al.,* 2023). The production of raw silk through the rearing of silkworms is called sericulture. Sericulture in rural areas generates employment, earns better returns, and has a regular and stable income at fixed intervals. The nature of the occupation is eco-friendly and women friendly. Further, the utilization and export of silk and silk goods at domestic and international levels contribute to the economy (Manjunath *et al.,* 2023). The silk industry is one of the significant employment-generating sectors of the country; the foreign exchange generated through exports is 211 million US dollars. India ranks second in the production of raw silk. In India, five different silkworms are generally reared commercially, of which the mulberry silkworm is the most important. The other non-mulberry silkworms include tropical tsar, temperate tsar, ere, and mega silkworms. Mulberry silk accounts for 75% of all silk production in India (Manjunath *et al.,* 2023). Mulberry is a perennial tree that belongs to the family Morce au, which is fed to the silkworm *Bombyx mori* (mulberry silkworm). It originated in the foothills of the Himalayas. The plant's economic part is its leaves, which are used as feed for silkworms (Manjunath *et al.,* 2023). The fruits of the mulberry tree are edible and a good source of vitamin C and iron, which are known to reduce blood sugar and cholesterol levels and improve digestion. Mulberry leaf extract also possesses anti-diabetic, anti-tumour, anti-oxidative, anti-inflammatory, and anti-microbial properties. The remnants of the mulberry plant can be used as fodder, fuel, and fertilizer (Manjunath *et al*., 2023).

Mulberry is a perennial tree belonging to the family *Moraceae,* which is of much economic value as its leaf is the only feed available for the silkworm *Bombyx mori*. Mulberry also yields several economically important products such as fruits, timber, and medicinally important compounds. Thus, it is widely grown in Asian countries. The taxonomy the of *Morus* is still wrapped under dispute as species delimitation is quite difficult due to the presence of abundant natural hybrids resulting from the open cross-pollination among the so-called species (Vijayan *et al.,* 2023). Nearly, 68 species have been defined, though most of them are still considered subspecies and varieties. Nonetheless, a few species such as *Morus alba, Morus bombycis, Morus indica, Morus latifolia,* and *Morus multicaulis* have received wide recognition, and some of them have been domesticated to harness their leaves and fruits (Vijayan *et al.,* 2023). The ploidy of mulberry varies from haploid with 14 somatic chromosomes to decasaploid with 308 chromosomes as most of the species can be vegetatively propagated (Vijayan *et al*., 2023). South Asia is considered the primary center of origin of mulberry; hence, it holds huge biodiversity. Therefore, major Asian countries like China, India, and Japan conserve a good amount (Vijayan *et al*., 2023).

Mulberry trees were well known in the ancient civilizations of the world. They were famous fruit trees, because of the delicious berry fruits that were abundantly produced by fast growing trees—loaded with huge green leaves that were eaten by livestock, along with the berries, and the leaves were used in the Orient to fatten silkworms for the silk trade. General Oglethorpe, in 1733, imported 500 white mulberry trees to Fort Frederica in Georgia to encourage silk production at the English colony of Georgia (Gardensaustralia, 2024). William Bartram, the famous early American explorer and botanist, described his encounter with mulberry trees near Mobile, Alabama, in his book, Travels, in the year 1773 (Gardensaustralia, 2024). Prince's Nursery in 1774 offered for sale 500 white mulberry trees, 'Morus alba' and 1000 black mulberry trees, 'Morus nigra,' at Flushing, New York. Documents show that America's first President, George Washington, bought fruit from this nursery (Gardensaustralia, 2024). Mulberry trees were planted in the landscape of President Thomas Jefferson 20 feet apart, and the fruit trees lined both sides of the road that extended around the house at Monticello, Virginia (Gardensaustralia, 2024). The silk trade was extremely important in the ancient civilizations in exchanges of fabrics, rugs, etc. The caravans of camels that traveled the "Silk Road" from Turkey to China brought world civilizations in contact with many valuable products back and forth to be traded, one of the most desirable and important products was silk. The mulberry trees, 'Morus alba,' were most desirable for silk production and gradually were filtered from Oriental societies to European fields. Many of these mulberry trees are grown today in Turkey, from where the famous Turkish silk carpets are distributed throughout the world (Gardensaustralia, 2024). Early Americans such as General Oglethorpe hoped to establish the silk industry in the American debtor colonies, but the project was destined for failure for many reasons. The mulberry trees are very fast growing fruit trees, and many farmers in the United States and other countries are hoping to profitably grow the trees for the production of human and livestock food. The wood of mulberry trees is very soft and is used for many purposes in many nations, but not extensively in the United States (Gardensaustralia, 2024). The white mulberry, 'Morus alba,' with the extremely large crop production of these trees has been observed growing as a fruit tree in North Carolina according to researcher, Russell Smith, in Tree Crops: A Permanent Agriculture that: white mulberry trees planted by a farmer "who kept pigs and claimed that one-third their weight was due to the mulberries falling from the trees—about 625 pounds of pork to an acre on rather thin, sandy land with little care and no cultivation." James A. Duke in Handbook of Energy Crops sees the mulberry fruit as a source of energy, "in South Korea on producing high yields of ethanol from mulberry trees " (Gardensaustralia, 2024).

Mulberry trees are considered to be a very important fruit tree in gardens of the Orient, Europe and the Mideast, and since new hybrid cultivars have been developed recently, the demand for these trees has surged in the U.S., where the grafted trees are rare, expensive and difficult to obtain. New cultivars are adaptable throughout the U.S. except Southern Florida, California and Arizona, and some trees offer stainless fruit, early bearing, rapid growth and delicious berry quality on berries that dangle from the stems, some tasting sweet as honey. These syrupy sweet mulberries are used in Ice Cream, jams, jellies, beverages, pies, and as stuffing mixtures for game birds (Gardensaustralia, 2024). The fast growing mulberry tree can grow as much as 3 m in one year, and as a rule will bear a few berries the first year, some with the richness of sweet cherries. The berries ripen to a brilliant black color, or red, pink, or white and are delectably fragrantly sweet and about two inches long, like a cooling blend and taste of raspberry and strawberry. The mulberry is excellent for fresh eating and for cooking pies. Some mulberries when dead ripe are so soft that just picking them breaks the fragile skin, staining your fingers purple with juice. This means that as a commercial berry available from grocery shelves, forget it, but nevertheless: the mulberries only need to travel as far as your mouth (Gardensaustralia, 2024). This choice mulberry fruit is practically seedless with a crisp, sweet flavor when eaten directly from the tree. Every child in your neighborhood will learn when the berries from this outstanding tree are ripening in early May. Most cultivars of hybrid mulberry trees are well adapted in most areas of the United States (Gardensaustralia, 2024). The dessert quality berries are excellent and honey sweet for picking directly off the tree and contain high concentrations of fruity sugar that makes the berries useful to process for jams, jellies and pies. The mature height of mulberry trees is 30 feet (Gardensaustralia, 2024). New grafted cultivars of mulberry trees are gaining lots of attention from the backyard gardener. Some of the recommended new cultivars of mulberry fruit trees are White Mulberry, 'Morus alba' 'Whitey;' Superberry Mulberry, 'Morus nigra' 'Superberry;' Black Beauty Mulberry, 'Morus nigra' 'Black Beauty' plant patent 4913; Pakistan Mulberry, 'Morus rubra' 'Pakistan;' Persian Mulberry, 'Morus nigra' 'Shah;' Bachuus Noir Mulberry, 'Morus nigra' 'Bachuus Noir;' and the Red Gelato Mulberry, 'Morus rubrum' 'Red Gelato" (Gardensaustralia, 2024).

Mulberry genus Morus grown as a perennial tree or shrub is an economically important plant used for Sericulture and it is the sole food plant for the domesticated Silkworm *Bombyx mori* L. Due to the presence of attractant, biting factor and swallowing factors, Silkworm is attracted towards mulberry. *Morus* which is widely distributed in Asia, Europe, North and South America and Africa is cultivated exclusively in East, Central and South Asia for silk production. People of Karnataka, Andhra Pradesh, North Eastern states and other parts of India much depend on Sericulture activities where only mulberry and its varieties are grown for the purpose of Silkworm rearing (UGC,2024). In this review article on Origin, Taxonomy, Botanical Description, Genetic Diversity, Breeding and Cultivation of Mulberry are discussed.

ORIGIN AND DISTRIBUTION

M. serrata, the Himalayan mulberry, is confined to the North Western belt in natural habitats. The sacred mulberry at Joshimath, Chamoli and Uttarakhand holds the oldest existing mulberry tree. M. serrata has a trunk girth of 21.34 m and is 1200 years old. M. serrata is widely distributed in Uttarakhand at Chakrata, Salna, Urgam Valley, Dehradun, Mussoorie, Pandukeshar, Hanumanchetti, Uttar kashi, Ranachetti, Almora, Pithoragarh, Nainital, Bhimtal, Gangnani, Gangotri, Yamunotri, Barkote and other places in a higher altitude range up to 2200 masl. *M. laevigata* is available all over India in wild and cultivated forms. In Uttarakhand, the species is available at Dehradun, Haridwar, Rishikesh, Tehri Garhwal, Rudraprayag, Uttarkashi, Haldwani, Chamoli, Almora, Bhimtal and Pithoragarh. M. indica is indigenous to India, is widely distributed in different parts of the country and is grown for fruit, fodder, fuel and timber. The present study indicates that wild resources of *M. indica* have become scarce due to deforestation. *M. alba* is a deciduous and dioecious tree species cultivated in different parts of the country particularly in traditional belt of sericulture in different states i.e., Andhra Pradesh, Jammu and Kashmir, Karnataka, Tamil Nadu and West Bengal for its foliage. In Uttarakhand, the species is available in and around Dehradun, Chamoli, Rudraprayag, Pauri Garhwal, Nainital, Almora and other places where sericulture is practiced. The species is native to China and is extensively cultivated throughout the plains of India and in the lower altitudes of the Himalayas (Tikader *et al.,* 2002). The centres of origin of crop plants placed the genus *Morus* in "China-Japan" region which includes East China, Korea and Japan (Tikader *et al.,* 2002). The genus Morus is distributed naturally in the Sub-Himalayan region up to an altitude of 2200 m extending between Indus and Brahmaputra rivers with varying climate from temperate to tropical. *M. serrat*a, the Himalayan mulbeny is available in natural habitat in North-western Himalaya. The natural and sacred mulbeny tree, belongs to *M. serrata* at Joshimath, is the oldest and about 1200 years old. Therefore, regular explorations are essential to identify the different locations of mulberry resources available in natural and cultivated habitats and to document the diversity of mulberry for further utilization in mulberry crop improvement programme (Tikader and Rao, 2002).

Genus *Morus* is placed in China-Japan region for the centre of origin. The Centre of Diversity of mulberry exists in the entire Himalayan belt where the natural mulberry and their wild relatives exist in abundance upto elevation of 2200 m MSL extending between Indus and Brahmaputra rivers (Rao *et al.,* 2005). Evidences gathered from fossils, morphology, anatomy and molecular biological investigations suggested that mulberry originated in the foothills of the Himalaya and later spread to major continents including Asia, Europe, North and South America, and Africa. Cultivation of mulberry and silkworm rearing started in China before 2200 BC. and currently mulberry is cultivated in almost all Asian countries (Vijayan *et al*., 2012). India is home to many fruits in the *Morus* genus, and it shares this distinction with parts of China and Pakistan. According to the book, "Agro Cottage Industry Sericature," mulberries originated near the lower slopes of the Himalayas. As early as 2800 BC, China's Chang Tong province grew mulberry trees commercially for its ever-expanding silk industry. Though white mulberries first grew in the Himlayan regions, The World Agro Forestry Center points to Persia as the black mulberry's origin. From this region, mulberry spread ancient Greece and Rome; and by the 12th century, Europe had both white and black mulberries (Earth of India, 2013). Mulberry originated in the lower Himalayan belt of Indo-China region, where some species are available in natural habitat upto an

elevation of 3500 meters above mean sea level. The major four indigenous species that are widely distributed in India comprise of *Morus alba, Morus indica*, *Morus laevigata*, *Morus serrata* where *M. serrata* is mainly confined to North Western Himalayan belt (Kala *et al.,* 2016)

Mulberry, Ramulus Mori or Sangzhi, is a native of China. India is the second largest cultivar of mulberry in terms of acreage. The fruit is relinquished for its delicious taste, pleasing colour, low-calorie content and high nutrient value and has been in use as folk medicine for thousands of years for treating sore throat, anemia, and tonsillitis. Hydroxystilbenes, resveratrol and oxyresveratrol, the major bioactive compounds with potent neuro-protectant and cardioprotective effect, are found in mulberry. In addition, oxyresveratrol is known to inhibit tyrosinase and hamper biosynthesis of melanin, a pigment responsible for hyper pigmentation of skin in patients (Hussain *et al.,* 2021). Morus, a genus of flowering plants in the family Moraceae, comprises 10–16 species of deciduous trees commonly known as mulberries, growing wild and under cultivation in many temperate world regions. Mulberry is also known as Ramulus Mori or Sangzhi. Mulberry is a native of China but is now widely cultivated throughout the world between 28°N and 55°N latitude (Hussain *et al*., 2021). Shahtoot trees were cultivated in the past for the purpose of sericulture (rearing silkworms). Silkworms feed on Mulberry leaves and produce silk. The practice of Sericulture began in China. Since then, it is thought that Mulberry originated in China. This was passed to India by Tibetan folks during 140 B.C. Shahtoot or Mulberry is a purple pink succulent fruit and can be found across India — from Karnataka, Andhra Pradesh to Himachal Pradesh and Punjab. The taste of each type may slightly vary from the other (Lifestyle Desk, 2022). The origins of most cultivated mulberry varieties are believed to be in the China/Japan area and the Himalayan foothills. It is one of the main species fed to silkworms. It is a short-lived, fast-growing, small to medium-sized tree that reaches heights of 10 to 20 m. Mulberry basically originated in the Himalayan foothills but distributed to continents like Asia, Europe, North and South America, and Africa and presently, mulberry is under cultivation in almost all Asian countries, including India (Manjunath *et al*., 2023)

Thus natural distribution covers wide areas of the globe. The wild mulberry grows in all the continents excepting Europe and ranges between latitude 100 and 500 north. In view of such natural distribution, mulberry is considered as a plant suited for tropical and temperate regions. It is known that though mulberry was not present in Europe but seems to have introduced from other regions (UGC, 2024). Black, red, and white mulberries are widespread in Southern Europe, the Middle East, Northern Africa, and the Indian subcontinent, where the tree and the fruit have names under regional dialects. Black mulberry was imported to Britain in the 17th century in the hopes that it would be useful in the cultivation of silkworms. It was much used in folk medicine, especially in the treatment of ringworms. Mulberries are also widespread in Greece, particularly in the Peloponnese, which in the Middle Ages was known as Morea, deriving from the Greek word for the tree *mouria* (Wikipedia, 2024).

TAXONOMY

Mulberry generally refers to various deciduous trees in the genus *Morus* (Wikipedia, 2024a).

- Chinese mulberry, several species in the genus *Morus*, as well as *Maclura tricuspidata*
- Indian mulberry, two species in the genus *Morinda*
- Paper mulberry (*Broussonetia papyrifera*, syn. *Morus papyrifera*)
- *Ficus sycomorus*, fig-mulberry
- *Hedycarya angustifolia*, Australian mulberry, native mulberry
- *Morus mesozygia*, black mulberry, African mulberry
- *Morus serrata*, Himalayan mulberry
- *Morus rubra*, red mulberry
- *Morus nigra*, black mulberry
- *Morus alba*, white mulberry
- *Pipturus argenteus*, native mulberry, native to Australia

Morus, a genus of flowering plants in the family Moraceae, consists of 19 species of deciduous trees commonly known as mulberries, growing wild and under cultivation in many temperate world regions. Generally, the genus has 64 subordinate taxa, three of which are well-known and are ostensibly named for the fruit color of the best-known cultivar: white, red, and black mulberry (*Morus alba*, *M. rubra*, and *M. nigra*, respectively), with numerous cultivars and some taxa currently unchecked and awaiting taxonomic scrutiny. *M. alba* is native to South Asia, but is widely distributed across Europe, Southern Africa, South America, and North America. *M. alba* is also the species most preferred by the silkworm, and is regarded as an invasive species in Brazil and the United States. The closely related genus *Broussonetia* is also commonly known as mulberry, notably the paper mulberry (*Broussonetia papyrifera*). Despite their similar appearance, mulberries are not closely related to raspberries or blackberries. All three species belong to the Rosales order. But while the mulberry is a tree belonging to the Moraceae family (also including the fig, jackfruit, and other fruits), raspberries and blackberries are brambles and belong to the Rosaceae family (also including the apple, peach, and other fruits) (Wikipedia, 2024).

The taxonomy of *Morus* is complex and disputed. Fossils of *Morus* appear in the Pliocene record of the Netherlands. Over 150 species names have been published, and although differing sources may cite different selections of accepted names, less than 20 are accepted by the vast majority of botanical authorities. *Morus* classification is even further complicated by widespread hybridisation, wherein the hybrids are fertile (Wikipedia, 2024). The following species are accepted (Wikipedia, 2024):

- *Morus alba* L. – white mulberry (China, Korea, Japan)
- *Morus australis* Poir. – East and South-East Asia
- *Morus boninensis* Koidz.
- *Morus cathayana* Hemsl. – China, Japan, Korea
- *Morus celtidifolia* Kunth – Texas mulberry (southwestern United States, Mexico, Central America, South America)
- *Morus indica* L. – India, Southeast Asia
- *Morus koordersiana* J.-F.Leroy
- *Morus liboensis* S.S.Chang – Guizhou Province in China
- *Morus macroura* Miq. – long mulberry (Tibet, Himalayas, Indochina)
- *Morus microphylla* Buckley
- *Morus miyabeana* Hotta
- *Morus mongolica* (Bureau) C.K.Schneid.
- *Morus nigra* L. - black mulberry (Iran, Caucasus, Levant)
- *Morus notabilis* C.K.Schneid. – Yunnan and Sichuan Provinces in China
- *Morus rubra* L. – red mulberry (eastern North America)
- *Morus serrata* Roxb. – Tibet, Nepal, northwestern India
- *Morus trilobata* (S.S.Chang) Z.Y.Cao – Guizhou Province in China
- *Morus wittiorum* Hand.-Mazz. – southern China

There are about 68 species recognized in the genus of which 24 species are represented in China, 19 in Japan, 6 in Korea, 4 each in Taiwan and India, 3 each in Myanmar and Indonesia, 2 each in Thailand, Vietnam and Afganistan and 1each in Arabia, Oman and Muscat. Further, 14 species are found in North America and 7 in Central and South America. In India, genus Morus is represented by four species *viz., M. indica, M. alba, M. serrata* and *M. Laevigara.* The natural distribution of the genus has considerably changed because of its extensive cultivation for silkworm rearing (Tikader and Rao, 2002). There are about 68 species recognized in the genus of which 24 species are represented in China, 19 in Japan, 6 in Korea, 4 each in Taiwan and India, 3 each in Myanmar and Indonesia, 2 each in Thailand, Vietnam and Afghanistan and 1 each in Arabia, Oman and Muscat. Further, 14 species are found in North America and 7 in Central and South America. *M. leavigata* is present in Andaman and Nicobar Islands (Tikader *et al.,* 2002).

It was reported four *Morus* species *viz., M. indica, M. alba, M. laevigata* and *M. serrata* occurring in India. Since then the distribution and variation of mulberry genetic resources in India including Andaman Islands have been systematically reported by several taxonomists and germplasm curators (Rao *et al*., 2005). Taxonomically, mulberry belongs to the genus *Morus* L. and has more than 68 species. Out of which, *M. alba*, *M. indica*, *M. nigra*, *M. latifolia*, *M. multiculis* are cultivated for silkworm rearing, *M. rubra* and *M. nigra* for fruits and *M. laevigata* and *M. serrata* for timber. It is pertinent to note here that only a small fraction of the total mulberry gene pool is used for developing varieties suitable for silkworm rearing and a great chunk of the gene pool is still left in the wilderness (Vijayan *et al*., 2012).

The *Morus* genus should be classified into eight species, including *M. alba*, *M. nigra*, *M. notabilis*, *M. serrata*, *M. celtidifolia*, *M. insignis*, *M. rubra*, and *M. mesozygia*. Furthermore, the classification of the internal transcribed spacer (ITS) sequences of known interspecific hybrid clones into both paternal and maternal clades indicated that ITS variation was sufficient to distinguish interspecific hybrids in the genus *Morus* (Qiwei *et al*., 2015). Mulberry leaves, particularly those of the white mulberry, *Morus alba*, are important as the food of the silkworm, the cocoon of which is used to make silk. *Morus alba* is also notable for the rapid release of its pollen, which is launched at over half the speed of sound. "This is the fastest motion yet observed in biology, and approaches the theoretical physical limits for movements in plants". Mulberry is a perennial tree being cultivated for sericulture purposes besides being used for multipurposes such as fruit, timber. So far 68 species have been recognized; only a few species such as *M. alba, M. bombycis, M. indica, M. latifolia* and *M. multicaulis* are cultivated for foliage and *M. nigra* for fruit. The remaining species along with several landraces of the cultivated species are considered wild, which were largely neglected (Tikader and Vijayan, 2017).

Taxonomical studies reveal that mulberry belongs to the genus *Morus* L. and more than 68 species have been recorded in this genus. Mulberries are native to temperate Asia and north America but are widely distributed across Europe, southern Africa, South America, and south Asia. It is a deciduous tree of the genus *Morus* of the flowering plant family Morceau. There are about 68 species of the genus *Morus*, the majority of which are found in Asia. The most widely recognized species of the genus *Morus* are the white mulberry (*Morus alba*), black mulberry (*Morus nigra*), and red mulberry (*Morus rubra*). White mulberry (*Morus alba*) has a wide distribution range in Asia, Europe, Africa, and the Americas (Manjunath *et al*., 2023).

The red mulberry (*Morus rubra*) of eastern North America is the largest of the genus, often reaching a height of 21 metres. It has two-lobed, three-lobed, or unlobed leaves and dark purple edible fruits (Petruzzello, 2024). White mulberry (*M. alba*), native to Asia but long cultivated in southern Europe, is so called because of the white fruits it bears; its leaves are used as food for silkworms. It is naturalized in eastern North America. Several useful varieties of the white mulberry are the cold-resistant Russian mulberry (*M. alba*, variety *tatarica*), introduced into western North America for shelterbelts and local timber use, and fruitless sorts such as the 'Stribling' and 'Mapleleaf' cultivars. The weeping mulberry (*M. alba* 'Pendula') is frequently used as a lawn tree (Petruzzello, 2024). Black mulberry (*M. nigra*), the most common species, is a native of western Asia that spread westward in cultivation at an early period. Up to the 15th century it was extensively grown in Italy for raising silkworms, but it has since been

superseded by white mulberry. Now an introduced species in North America, it is mainly cultivated for its large juicy purple-black fruits, which are superior in flavour to those of red mulberry (Petruzzello, 2024). There are about 68 species of the genus *Morus.* The majority of these species occur in Asia, especially in China (24 species) and Japan (19). Continental America is also rich in its *Morus* species. The genus is poorly represented in Africa, Europe and the Near East, and it is not present in Australia. In India, there are many species of *Morus*, of which *Morus alba, M. indica*. *M. serrata* and *M. laevigata* grow wild in the Himalayas. Several varieties have been introduced belonging to *M. multicaulis*, *M. nigra*, *M. sinensis* and M. *philippinensis*. Most of the Indian varieties of mulberry belong to *M. indica*. In China there are 15 species, of which four species, *Morus alba*, *M. multicaulis*, *M. atropurpurea* and *M. mizuho* are cultivated for sericulture. In the former Soviet Union *M. multicaulis*, *M. alba, M. tartarica* and *M. nigra* are present (Datta, 2024).

Taxonomic classification of *Morus* L. (Mulberry) is given in Table 1.

Table 1. Taxonomic classification of *Morus* L.

Family	Moraceae-Mulberry family
Genus	*Morus* L. (mulberry)
Species	1. *Morus alba* 2. *Morus australis* 3. *Morus cathayana* 4. *Morus macroura* 5. *Morus mongolica* 6. *Morus nigra* 7. *Morus notabilis* 8. *Morus serrate* 9. *Morus celtidifolia* 10. *Morus insignis* 11. *Morus microphylla* 12. *Morus rubra* 13. *Morus mesozygia* 14. *Morus indica*

The taxonomy of mulberry is confusing, complex and disputed. Over 150 names have been published and different sources may cite different selections of accepted names, only 10-16 are generally cited as being accepted by vast majority of Botanical authorities. Morus classification is further complicated by wide spread hybridization, where hybrids are fertile (UGC,2024).

Characteristics of four cultivated species is given in Table 2.

Table 2. Characteristics of four cultivated species

Characters	*M. indica*	*M. alba*	*M. laevigata*	*M. serrata*
Bark colour	Brown, grey, blackish brown	Brown, dark brown	Brown, grey, greenish grey, grey blackish	Brown, dark brown, blackish brown
Leaf lobation	Lobed, unlobed, mixed	Unlobed, lobed	Lobed, unlobed, highly dissected	Lobed, unlobed, dissected, mixed
Leaf texture	Coriaceous, chartaceous	Coriaceous, chartaceous	Coriaceous, chartaceous	Coriaceous, chartaceous, leathery
Leaf shape	Wide ovate, ovate	Ovate, narrow ovate	Ovate, wide ovate, long ovate	Wide ovate, narrow ovate, ovate
Leaf margin	Serrate, crenate, dentate	Serrate	Serrate	Serrate, dentate
Leaf surface	Smooth, slightly rough	Smooth	Smooth, rough	Smooth, slightly rough, rough
Leaf size (L × B) cm	13.3 × 12.0 to 20.0 × 12.0	14.0 × 12.0 to 15.5 × 12.5	15.0 × 11.0 to 18.0 × 12.0	15.0 × 10.0 to 20.5 × 20.0
Sex	Male, female	Male, female	Male, female	Male, female
Catkin length (cm)				
Male	2.0 - 3.5	1.5 - 2.5	4.0 - 9.0	2.5 - 5.0
Female	1.5 - 3.0	1.2 - 2.0	7.0 - 12.0	3.0 - 4.5
Phyllotaxy	1/2,1/3,2/5	1/2,1/3	1/2	1/2,1/3,2/5
Internodes distance (cm)	3.8 - 5.5	3.5 - 4.0	6.0 - 7.0	4.0 - 7.0
Fruit length (cm)	2.0 - 3.0	2.0 - 3.5	7.0 - 14.0	3.5 - 4.5
Fruit colour	Black	White, pink	Green, white, pink	Black, pink
Fruit taste	Sour, sweet	Very sweet	Very sweet	Very sweet
Altitude (m)	580 - 1340	580 - 1350	600 - 1500	750 - 3500

Synonyms of *Morus alba is given as follows: Morus alba* f. *tatarica* Ser., *Morus alba* var. *constantinopolitana* Loudon, *Morus alba* var. *multicaulis* (Perr.) Loudon, *Morus indica* L., *Morus multicaulis* Perr. (Heuzé *et al.,* 2019).

BOTANICAL DESCRIPTION

Plants belonging to the genus *Morus* are arbor or deciduous with scaly bark. The plants have latex and winter buds with scaly coverings. The leaves are broad and may be lobed or entire. The leaf margin is denticulate and the leaves are alternate. The petiole has pair of stipules at the base and leaves fall early. The flowers are usually unisexual and rarely bisexual. The small flowers collectively formed in inflorescence. The inflorescence can be female or male and when the female inflorescence matures, it gives

rise to syncarp. The male inflorescence falls off early. On the basis of the presence of male and female flowers, plants were classified as bisexual or unisexual. Mulberry is swift growing when young, but soon become slow growing and rarely exceed 10-17 m tall. The leaves are alternatively arranged, simple often lobed, more often lobed on juvenile shoots than on mature trees and serrated on the margin. Depending on the species, the plant may be monoecious or dioecious. Multiple fruit with 2-3 cm long and fruits when mature are white or green to pale yellow with pink edges. In most species the fruits are red when ripened turning dark purple to black and have a sweet flavor. The fruits of the white fruited cultivar of the white mulberry are green when young and white when ripe (UGC, 2024).

Black mulberry (*Morus nigra* L.) is is a small deciduous tree cultivated worldwide, mainly for its edible fruits. Its leaves, like those of the white mulberry (*Morus alba* L.) can be used to feed silkworms but the silk is of lesser quality. The leaves are used as cattle fodder. Black mulberry is a dark green coloured deciduous shrub, medium-sized tree, growing up to 6-9 (-15-35) m in height which has a broad, dense spreading crown. The trunk is short. The leaves are petiolate, leathery (scabrous on the upper face and pubescent on the lower), large (5-16 x 5-16 cm), variable in shape: whole or palmately lobate. The leaf blades are assymetrical, broadly ovate, deeply cordiform at the base and shortly acuminate on top, obtusely dentate along the edge. Flowers are small, unattractive, clustered in catkin-like inflorescences. Fruits are 1.5-2.5cm in length and 3 cm in diameter, black, glossy, sweetish sour, juicy, and very tasty. Compared to the white mulberry, the black mulberry tree is shorter, with a smaller and more regular crown. Its shoots and branches have a bright yellow colour. The fruits of *Morus nigra* ripen earlier and are smaller, juicier, and tastier than those of *Morus alba* (Heuzé *et al*., 2019a).

White mulberry (*Morus alba* L.) is a high-yielding pantropical and subtropical medium-sized tree. While it is traditionally used as fodder for silkworms, white mulberry provides a highly palatable forage suitable for most farm animals. *Morus alba* is a fast growing, deciduous, medium-sized tree that grows to a height of 25-35 m. It has a dense spreading crown, generally wider than the height of the tree. White mulberry can have a pyramidal shape or have a drooping habit. Its bole is straight, cylindrical without buttresses and up to 1.8 m in girth. The bark is vertically fissured, dark greyish-brown in colour, exuding a white or yellowish latex. The leaves are light green in colour, alternate, petiolate, cordate at their base and very variable in shape. They can be simple or compound (3-5 lobed) even on the same tree, dentate, palmately veined, coriaceous and caducous. The inflorescence is axillary and pendulous. The flowers are unisexual inconspicuous, greenish in colour, looking like catkins (male flowers) or spikes (female flowers). The trees are monoecious or dioecious without buttresses. The fruit is a 5 cm long fleshy, juicy, edible but not very tasty berry that consists in a syncarp of achenes enclosed in succulent sepals. The seeds are very small and the 1000-seed weight is 2.2-2.3 g. It is thought that the genus name *Morus* comes from the latin word "mora" which could have referred to the late expansion of the buds. A celtic etymology "mor" has been proposed according to the colour of the fruit in the genus. The binomial taxon *Morus alba* may have been chosen after the light-coloured buds and not after the colour of the fruits (Heuzé *et al*., 2019).

Mulberries grows on perennial, deciduous small to medium sized trees and shrubs with alternate, broad but lobed leaves. The plant is either monoecious or dioecious. Mulberry trees attain the height of 6-9 m. The life expectancy of this plant is around 300 years. The bark of the tree consists of narrow scaly ridges. However, it appears smooth and colour ranges from light brown to grey. The leaves are simple, serrate or dentate, oval in shape, and 5-15 cm long. Lobes are more common on juvenile shoots than on mature trees. The flowers are small, greenish, present in clusters. Mulberry bear flowers in January, while fruits are produced in the months of January and February, and can be harvested from March to April. The mulberry fruit is a multiple fruit, 2–3 cm long and weigh around 5–6 g. Immature fruits are white, green or pale yellow. In most species the fruits turn pink first, then red and finally attains purple colour as ripening proceeds. The fruit is similar to blackberry *i.e.* white but sometimes pinkish violet, insipid. The fruits of the white-fruited cultivar are white when ripe; the fruit of this cultivar is also sweet, but has a very bland flavour compared with darker varieties (Hussain *et al*., 2021).

In temperate climates, trees are often deciduous. However, trees cultivated in tropical areas may be evergreen. It is a 10–20 m tall, small to medium-sized mulberry tree that grows quickly (10-20). The leaves on young, active stems can grow to be up to 30 cm long, are serrated and occasionally lobed, and are placed alternately along the stems. Each fruit, referred to as a multiple, derives from an entire flower cluster. It bears sweet edible berries, which can be eaten when it is ripe. The fruit's colour cannot determine the mulberry species. For instance, white mulberries might yield white, lavender, or black fruit. The best varieties of red mulberry have fruits that are often deep red, almost black. Black mulberry fruits are large, juicy, and delicious, with an excellent combination of sweetness and acidity. The trees can be dioecious or monoecious; the flowers are held on short, green, pendulous catkins that develop in the axils of the current season's growth and on spurs on older wood. Intense catkin clusters contain minute flowers. Flowers are yellowish green. The wind pollinates them, and some cultivars will produce fruit without being pollinated. Female catkins are ovoid and stalked, whereas male catkins are cylindrical and broad. Female spikes catkins are also shorter than male spikes. Clusters of small fruits from mulberries are placed longitudinally along the central axis. The Mulberry ovary is unicellular and has bifid stigmas. Fruits have many drupes enclosed in a fleshy perianth, up to 5 cm long, sub-globose or ovoid. A bifid stigma is present in the unicellular mulberry ovary (Manjunath *et al.,* 2023).

Mulberries are fast-growing when young, and can grow to 24 m tall. The leaves are alternately arranged, simple, and often lobed and serrated on the margin. Lobes are more common on juvenile shoots than on mature trees. The trees can be monoecious or dioecious. The mulberry fruit is a multiple, about 2–3 centimetres long. Immature fruits are white, green, or pale yellow. The fruit turns from pink to red while ripening, then dark purple or black, and has a sweet flavor when fully ripe (Wikipedia, 2024). Male and female flowers are borne separately, usually on different trees (dioecious), in clusters called catkins, a few catkins emerging from buds along 1-year-old branches at about the same time as the leaves. Male catkins are ascending to pendulous in flower, ¾ to

2 inches long, green to yellowish, each flower in the cluster with 4 stamens. Female catkins are erect to ascending and more compact, oval to short-cylindric, to 3/8 inch long, each flower with a somewhat flattened, oval green ovary and a whitish to reddish, 2-parted style. Cluster stalks on both male and female catkins are hairy. Mulberries are deciduous and have toothed, sometimes lobed leaves that are alternately arranged along the stems. Individuals can be monoecious (bearing both male and female flowers) or dioecious (bearing only male or female flowers). The minute flowers are borne in tight catkin clusters. Each fruit develops from an entire flower cluster and is formally known as a multiple. The fruits somewhat resemble blackberries and ripen to white, pink, red, or purple (Petruzzello, 2024).

Mulberry is a fast growing deciduous woody perennial plant. It has a deep root system. The leaves are simple, alternate, stipulate, petiolate, entire or lobed. The number of lobes varies from one to five. Plants are generally dioecious. Inflorescence is catkin with pendent or drooping peduncle bearing unisexual flowers. Inflorescence is always auxiliary. Male catkins are usually longer than the female catkins. Male flowers are loosely arranged and after shedding the pollen, the inflorescence dries and falls off. These are four persistent parianth lobes and four stamens implexed in bud. Female inflorescence is usually short and the flowers are very compactly arranged. There are four persistent parianth lobes. The ovary is one-celled and the stigma is bifid. The chief pollinating agent in mulberry is wind. Mulberry fruit is a sorosis, mainly violet black in colour (Datta, 2024). *Morus alba* is a small, 9.1-15.2 m tall, deciduous tree that invades disturbed areas throughout the United States. The alternate leaves are polymorphic (variably shaped), 5.1-20.3 cm long and shiny with blunt teeth and heart-shaped bases. Young bark, the bark along the roots, and the inner bark along the trunk are often bright orange in color. Older bark is gray with narrow, irregular fissures. Flowering occurs in April. Plants are normally dioecious (male and female flowers on separate plants). Male flowers are small, green and occur in 2.5-5.1 cm long catkins. Female flowers are inconspicuous and crowded in short spikes. ruits are multiple-seeded berries. They can range in color from black to pink or even white when ripe (WM, 2024).

Mulberry is the name given to several species of deciduous shrub or tree in the genus *Morus* (family Moraceae) which are grown for their edible fruits. The genus includes white mulberry (*Morus alba*) and red mulberry (*Morus rubra*). Mulberries are small to medium sized shrubs or trees with a thick tan-gray ridged trunk and light green leaves which vary in shape depending on variety. Leaves are arranged alternately and are lobed or unlobed, cordate (heart-shaped), dentate (toothed) and acuminate (tapering). The trees produce small green-yellow flowers in dense spikes and an oval aggregate fruit made up of individual drupelets. The fruit can be white, pink or purple to purple-black in color and contains numerous brown seeds. Mulberry can reach a height of 15 m and are quite short lived, with an economic lifespan of around 15 years. Mulberry is believed to originate from China (Plantvillage, 2024). Botanical Description of mulberry is given in Fig. 1.

		
White mulberry tree	**A mulberry tree in England**	**Trained mulberry tree in block and**
		
Female inflorescence	**Male catkins**	**Female catkins**

Continue …….

Immature fruit

Unripe white mulberries

White mulberries

red mulberry

Berries on branches

Luxuriant leaf

A silkworm, feeding on a mulberry tree

Domesticated silkworms on mulberry leaves

Fig. 1. Botanical Description

GENETICS AND CYTOGENETICS

The meiotic numbers of *Morus indica* L. and *Morus laevigata* Wall, were confirmed to be as n = 14 and n = 28 respectively. Secondary association of bivalents indicates 7 as basic number. In *M. laevigata* the following peculiarities were noted in its meiotic behaviour: I) presence of multivalents and laggers; II) irregular separation of chromosomes; III) unequal numbers of chromosomes in different PMCs. The allopolyploid nature of *M. indica* and polyploid state of *M. laevigata* have been suggested (Das, 1960). Natural polypoids are common in mulberry, though diploids with 28 chromosomes ($2n = 2x = 28$) or triploids with 42 chromosomes ($2n = 3x = 42$) are more frequent. Tetraploids with 56 chromosomes ($2n = 4x = 56$), hexaploids with 84 chromosomes ($2n = 6x = 84$) and octaploids with 112 chromosomes ($2n = 8x = 112$) are also found in nature (Basavaiah *et al.* 1989). Chromosomes of mulberry are small as the length varies from 1.17 µm to 5.23 µm (Vijayan *et al*., 2012).

Its chromosome number varies from 2n = 28 to 2n = 308 with ploidy level from x to 22x. In the present investigation, three triploid mulberry varieties, namely, S 41, S 1635 andBC 2–59 , have been analyzed for detailed meiotic studies. Based on the chromosome configuration and other meiotic behaviour, x = 14 has been considered as the basic number of the genus. Meiosis was highly irregular. Various anomalies, such as the occurrence of two nucleolus, association of single trivalent with nucleolus, unequal separation and precocious movement of chromosomes, laggards, and occurrence of multivalents, have been observed. The low pollen fertility and seed set may be due to genic or physiological causes (Venkatesh *et al*., 2014). Most of the species of the *Morus* are diploid having 28 chromosome, but a few species, namely, *M. tiliafolia Makino*, *Morus cathyana* and *M. nigra L*., are higher polyploidy. Chromosome number varies from 2n =28 to 2n = 308 with ploidy level from x to 22x. In the present study two diploid mulberry varieties namely, Kollegal and DD have been analyzed for both mitotic meiotic studies. Based on the somatic chromosome number, ploidy level, chromosome configuration and other meiotic behavior x = 14 have been considered as basic number of the genus. Meiosis showed marginal differences. Various meiotic abnormalities like occurrence of one large chromosome, stickiness and loose association of chromosomes at metaphase I, unequal separation at anaphase I, laggards, precocious movement and unequal separation of chromosomes at anaphase II, have been observed. The low pollen fertility and seed set may be due to irregular chromosomal pairing and separation rather than due to genic or physiological causes (Venkatesh and Munirajappa, 2014.).

In mulberry, chromosome numbers are varies from 2n = 28 to 22n = 308 (Diploid to Decosoploid) with ploidy level x to 22x. Based on chromosome numbers and meiotic behaviors x = 14 has been considered as basic chromosome numbers of the genus. In the present study, two diploids, two uneuploids, two triploids and two teteraploids mulberry varieties were selected for detailed chromosomal numbers and meiotic behaviors belongs to three species, namely Morus indica, Morus alba and Morus latifolia. Varieties, Vishaala and Kosen were diploids with 2n = 2x = 28 chromosomes and varieties Ber-S1 and S13 were uneuploids with 2n = 30 chromosomes belongs Morus indica. Varieties NAO Khurkul and KPG-1 were triploids with 2n = 3x = 42 chromosomes belongs to Moru alba and varieties Kokuso and Icheihei were tetraploids with 2n = 4x = 56 chromosomes. Diploids and uneuploids were showed normal meiosis with high pollen fertility and triploids and teteraploids were showed abnormal meiosis with low pollen fertility, due to virtue of higher ploidy level have been discussed in this chapter (Venkatesh, 2021).

Among the germplasm belonging to 16 species, we identified 122 diploids (2n = 28), 4 aneuploids (2n = 30), 13 triploids (2n = 42), 15 tetraploids (2n = 56), 7 hexaploids (2n = 84) and 1 dodecosaploid (2n = 308) based on the chromosome count. Most of the cultivated mulberries are found to be diploids. The mean nuclear 2C DNA content estimated by Flow cytometry, varied from 0.723 ± 0.006 pg (M. australis, 2n = 2x) to 7.732 pg (*M. nigra*, 2n = 22x). The 2C DNA content positively correlated with the ploidy status and stomatal length ($r = 0.814$, $p < 0.001$). Based on the 1Cx value, the study also suggests that the majority of the polyploid species have experienced genome downsizing in relation to their diploid progenitors. This study provides the most essential information on chromosome number, ploidy and DNA content to facilitate the utilization of a core subset of germplasm in the mulberry breeding program (Kruthika *et al*., 2023). In this present research, a core set of 157 germplasm accessions belonging to eight accepted species of *Morus* including promising functional varieties were chosen to represent the genetic spectrum from the whole germplasm collection. To estimate the GS, accessions were subjected to flow cytometry (FCM) analysis and the result suggested that four different ploidies (2n = 2x, 3x, 4x, and 6x) with GS ranging from 0.72±0.005pg (S-30) to 2.89±0.015pg (*M. serrata*), accounting~4.01 fold difference (Gnanesh *et al*., 2023). This genus has diverse ploidy levels; *Morus* species with 14, 42, 56, 84, 140, and even 308 chromosomes with ploidy levels x to 22x are found (Manjunath *et al*., 2023). Most of the species of the genus *Morus* and cultivated varieties are diploid, with 28 chromosomes. However, triploids (2n=(3x)=42) are also extensively cultivated for their adaptability, vigorous growth and quality of leaves (Datta, 2024).

GENETC DIVERSITY

Extensive explorations were undertaken in different regions ofv India. A total of 367 mulberry germplasm were collected through 38 exploration covering 58 districts. Cosiderable diversity was observed in *Morus* germplasm collected through explorations (Tikader *et al*., 2002). Nine isozyme patterns were studied to deduce the level of genetic diversity and inter-relationships among 14 species of mulberry (*Morus* spp. L) used in breeding programmes. *β*Esterase (EST), peroxidase (PoX), diaphorase (DIA), and polyphenol oxidase (PPO) produced 12 isozyme loci and a total of 22 alleles. The percentage of polymorphic loci and the average number of alleles per locus ranged from 50 – 75% and 1.336 – 1.667 respectively. Among 80 wild accessions of two wild and two domesticated species of *Morus*, 22 accessions of *M. alba* exhibited a higher number of polymorphic loci (75%), a higher polymorphic index (0.398), average number of alleles per locus (1.457), and expected heterozygosity (0.339) compared to the three other *Morus* species under study. Evidence for a higher rate of gene flow was found between populations of *M. alba* and *M. indica* compared to that between the other three species sampled. Phylogenetic clustering of the 80 wild mulberry accessions indicated three major groups. Accessions of the domesticated species grouped into one cluster, while accessions of the wild species grouped into one major and one minor cluster. Among all the isozyme loci, EST-2 was present only in polyploid species. The resolving power of isozymes was less than that of molecular markers, hence molecular markers should be used for phylogenetic studies in mulberry (Rao *et al*., 2011).

Tikader (2011) observed the following variations in the cultivated species (Fig. 2).

The Indian sub-continent is an important center of origin of diversity of nearly 160 domesticated plant species of economic importance. Mulberry is one of them and is cultivated not only for sericulture but also for fruits, fodder, timber, fuel, wood etc. There are 4 species of mulberry *viz*. *Morus indica*, *M. alba*, *M. laevigata* and *M. serrata* occurring in India and are found throughout the Himalayas from Kashmir in West to Assam in East. Because of its adaptabilty to cross pollination with no inter-specific reproductive barriers a vast range of diversity in the genetic stocks has crept in thereby rendering it highly heterozygous plant species as a result every plant being different from other in natural population. To augment the diversity in true sense the characterization of the texa is essential and the magnitude of diversity that has crept in the genetic stocks of the indigenous origin as regards to various qualitative characters, morphology, anatomy, propagation, reproduction, growth and biochemistry (Bindroo *et al*., 2012).

Morus alba, known as white mulberry, is widely cultivated to feed the silkworms employed in commercial production of silk. The present study was undertaken to estimate the genetic variations and relationships between fourteen *M. alba* and two *Morus lhou* (ser) *koidz* cultivars in order to improve the yield and fruit quality of mulberries using the RAPD and ISSR markers with a set of 40 RAPD primers and 10 ISSR primers. Polymorphism exhibited by RAPD, ISSR and RAPD + ISSR primers among the sixteen samples were 66.67%, 55.05% and 64.11% respectively. To unriddle the genetic relationship between mulberry varieties, genetic dissimilarity coefficients were estimated for each pair of accessions. The dissimilarity coefficients ranged between 0.123–0.378 and 0.095–0.285 for RAPD and ISSR markers respectively. Dendrogram generated by UPGMA clustering method clustered the genotypes into three and four groups by RAPD and ISSR fingerprinting respectively. The Enchalang and Guksang16ho were found to be closely related.

Fig. 2 (A, B*) Morus alba* flower, fruit; (C, D) *M. indica* flower, fruit; (E, F) *M. laevigata* flower, fruit; (G, H) *M. serrata* flower, fruit; (I, J, K, L) Leaf of *M. alba, M. indica, M. laevigata, M. Serrata*

To analyze the faithfulness of dendrogram generated, cophenetic correlation coefficient was also calculated and it was found to be significant. The primers OPA-6, OPA-14, OPY-15, UBC-14 and UBC-17 gave higher average polymorphic index value (Kalpana *et al*., 2012).

Mulberry is essential for sericulture industry as the primary source of food for silkworm *Bombyx mori* L. In India, long tradition of practising sericulture includes the use of a large number of indigenous cultivars. Since knowledge on genetic divergence of these cultivars/varieties is imperative for conservation and gainful utilization, simple sequence repeat (SSR) profiling was employed toassess genetic relatedness among 17 mulberry genotypes maintained in the Germplasm Bank of Temperate Sericulture Institute, SKUAST Kashmir, Mirgund. Six SSR primers were utilised which generates 17 alleles among the genotypes. The polymorphism information content (PIC) value varied from 0.260 (MulSTR3) to 0.623 (MulSTR4), with an average of 0.438 per locus. The highest similarity value of 0.92 was observed between Lemoncina and Kanva-2, as compared to the lowest similarity coefficient of 0.15 was between SKM-48 and Chinese white. Clustering of the genotypes was done with unweight pair group method using arithmetic average (UPGMA) which generates five clusters. Cluster-2 contained maximum (six) genotypes (Wani *et al.,* 2013). Mulberry is essential for sericulture industry as the primary source of food for silkworm *Bombyx mori* L. In India, long tradition of practising sericulture includes the use of a large number of indigenous cultivars. Since knowledge on genetic divergence of these cultivars/varieties is imperative for conservation and gainful utilization, simple sequence repeat (SSR) profiling was employed to assess genetic relatedness among 17 mulberry genotypes maintained in the Germplasm Bank of Temperate Sericulture Institute, Kashmir, Mirgund. Six SSR primers were utilised which generates 17 alleles among the genotypes. The polymorphism information content (PIC) value varied from 0.260 (MulSTR3) to 0.623 (MulSTR4), with an average of 0.438 per locus. The highest similarity value of 0.92 was observed between Lemoncina and Kanva-2, as compared to the lowest similarity coefficient of 0.15 was between SKM-48 and Chinese white. Clustering of the genotypes was done with unweight pair group method using arithmetic average (UPGMA) which generates five clusters. Cluster-2 contained maximum (six) genotypes (Wani *et al.,* 2013).

A total of 72 collections belonging to two wild mulberry species, *viz.*, *Morus laevigata* and *M. serrata*, from different eco-geographic regions of India were utilized for assessment of molecular diversity and interrelationships. The study employed a total of 21 RAPD and 6 ISSR primers and generated 409 markers, of which 92.4% were polymorphic. Among *M. laevigata* collections, genetic divergence was significant between the mainland and Andaman Island collections, highlighting the geographical and reproductive isolation among the two populations. Hierarchical clustering of molecular marker similarity coefficients by UPGMA method resolved the collections into three distinct clusters, first one having all the *M. laevigata* collections of the mainland, second comprising of *M. laevigata* collections from the Andaman Islands and the third containing *M. serrata* collections exclusively. This is in concurrence with the geographical distribution and taxonomic status. Three *M. laevigata* (OPA-09900, OPA-092400 & UBC-8113500) and two M. serrata (OPA-16650 & UBC-8071450) specific DNA markers were identified for possible conversion into SCAR markers for diligent identification of wild mulberry species. The results obtained from the analysis of molecular diversity and coefficient of variance indicated the need for immediate *in situ* conservation measures for wild mulberry. species, especially the *M. serrata* population of India (Naik *et al*., 2015).

The present communication deals with the distribution of mulberry species in J & K. There are 4 indigenous species of mulberry *viz Morus indica, M. alba, M. laevigata and M. serrata*. Jammu and Kashmir State has the privilege of possessing all the four indigenous species of mulberry. Because of its adaptability to cross pollination with no inter-specific reproductive barriers a vast range of diversity in the genetic stocks has crept in thereby rendering it highly heterozygous plant species as a result every plant

being different from other in natural population. Keeping this in view and to assess the diversity of mulberry under extreme cold climatic conditions, survey of Ladakh, Lolab (Kupwara) and Gurez (Bandipora) in Jammu and Kashmir was undertaken. Mulberry sericulture is presently not being practiced in these regions except at Lolab (Kupwara). However the genetic potential of these wild genotypes can be utilized for bioprospecting of frost tolerant characters (Shabnam *et al.,* 2016). The morphological aspects considered in the present study revealed high variability. The number of leaves per meter twig was highest in Tree-10 and Chakmajra (22). Maximum inter-nodal distance was recorded in variety MS-9 and Chinese White (5.7cm). Actual leaf area was highest in LUN-10 (225.38cm^2). The fresh weight of 100 leaves was highest in Kokuso-27 (339.0g) and dry-weight as (101.5g). Maximum leaf length observed was 23.0 cm in V-1 and maximum width of 17.3 cm was recorded in Kokuso-27. For molecular assessment of genetic diversity, nine reproducible RAPD primers were used that revealed more than 97.22 % polymorphism percentage with 0.32 average PIC value. Finally, the cluster analysis based on UPGMA divided the varieties in two major groups. Based on morphological and molecular analysis, diverse varieties having better agronomic traits can be selected as the parental source in developing new hybrids. Moreover, the RAPD profiles of each variety obtained from molecular analysis can be used to depict the authenticity of a cultivar and confirmation of hybrid variety (Kala *et al.,* 2016)

Fruit shape of mulberry genotypes varied from pendulous, oblong to subglobose (Fig. 3) (Krishna *et al*., 2018).

Fig. 3. Variations in fruit shapes and colour of mulberry **genotypes**

Mulberry leaves are sole food for silkworms in sericulture. Breeding is necessary for these plants to develop varieties of mulberry with improved yield, quality, and tolerance to drought and diseases. Thus, in the present study an attempt has been made successfully to assess the genetic diversity among Mulberry varieties by using RAPD marker. A total 10 collections of mulberry varieties from various eco-geographical regions of India were utilized to assessment of molecular diversity and interrelationship. The isolated and quantified DNA was amplified using10 RAPD markers. RAPD analysis generated total 409 bands with 306 polymorphic bands. Most of the RAPD markers show in an average 75% polymorphism. The similarity coefficient of pair wise Nei and Li's value range between 0 to 7.39 for 10 varieties of Mulberry plants. A dendrogram was constructed using Un-weight Pair Group Method with Arithmetic Mean (UPGMA) revealing 6 clusters with wide range of dissimilarity values showed a high degree of diversity among the cultivars. Thus, all the accessions studied are genetically highly polymorphic, and the information generated can be used to design strategies for conservation of germplasm in plant breeding programmes (Manjula *et al*., 2020). The genetic divergence of 25 mulberry genotypes from various agroclimatic environments in India was examined using 14 morphometric characteristics. A wide diversity of germplasm is essential for any breeding program (Manjunath *et al.,* 2023).

BREEDING

Gemplasm

Extensive explorations were undertaken in different regions of India. A total of 367 mulberry germplasm were collected through 38 explorations covering 5 zones, 21 states and 58 districts. The wild collections of *Morus serrata* was confined to North-western Himalaya. *M. laevigata* in natural forms are available in North-eastern, North-western and South India including Andaman and Nicobar Islands. Introduced genepool of mulberry were collected from Madhya Pradesh, Chhattisgarh, Tamil Nadu, Kerala, Karnataka, Maharashtra and other parts of India which are maintained as avenue trees, shade trees, social forestry and fruit trees mainly in coffee and tea estates. *M. alba* and *M. indica* are mostly found in cultivated forms throughout India. Considerable diversity was observed in *Morus* germplasm collected through explorations (Tikader *et al.,* 2002). The occurrence of mulberry is reported in different regions of India. Explorations for mulberry genetic resources were undertaken in Central Himalayas, North-eastern India, North-western Himalayas ; reported the distribution of *M. indica, M. serrata* and *M. laevigata* in forest flora of Kumaon region and North-eastern India, respectively, have extensively explored Kerala for mulberry resources and collected from farm backyard/cultivated gardens, tea and coffee estates (Tikader *et al.,* 2002). Among the sericultural countries, China is holding largest mulberry germplasm collections (2600 accessions) followed by Japan (1375), India (1053), Korea (615) and

Bulgaria (140) in the *ex situ* field gene banks. The Central Sericultural Germplasm Resources Centre, Hosur (Karnataka) is the National Active Germplasm Site (NAGS) for mulberry in India and ismandated to collect, characterize and conserve the mulberry genetic resources. This centre conducted more than 50 survey exploration trips across the country and collected more than 660 mulberry genetic resources. Ladakh region of Jammu and Kashmir state remained unexplored till recently. Hence, an attempt was made to explore and survey cold deserts of Ladakh region for collection of frost tolerant mulberry genetic resources and identify locations for mapping mulberry genetic resources, so that longterm conservation strategies could be evolved (Rao *et al*., 2005). Large numbers of germplasm accessions are available in China, India, Japan, Korea and Vietnam (Table 3). China has more than 1860 germplasm accessions, Japan has 1375 germplasm accessions, Korea has 614 accessions while India has more than 1120 germplasm accessions (Vijayan *et al*., 2012).

Table 3. Germplasm collections in different centres

Species	Japan	China	India	Korea
M. bombycis Koidz.	583	22	15	97
M. latifolia Poir.	349	750	19	128
M. alba L.	259	762	93	105
M. acidosa Griff.	44	–	–	1
M. wittorium Hand-Mazz.	–	8	–	–
M. indica L.	30	–	350	5
M. mizuho Hotta	–	17		–
M. rotundiloba Koidz.	24	4	2	–
M. kagayamae Koidz.	23	–	–	1
M. australis Poir.	–	37	2	–
M. notabilis C.K. Schn.	14	–	–	–
M. mongolica Schneider		55	–	–
M. boninensis Koidz.	11	–	–	–
M. nigriformis Koidz.	3	–	–	–
M. atropurpurea Roxb.	3	120	–	–
M. serrata Roxb.	3	–	18	–
M. laevigata Wall.	3	19	32	1
M. nigra L.	2	1	2	3
M. formosensis Hotta.	2	–	–	–
M. rubra L.	1	–	1	–
M. mesozygia Stapf.	1	–	–	–
M. celtifolia Kunth.	1	–	–	–
M. cathayana Hemsl.	1	65	1	–
M. tiliaefolia Makino	1	–	1	14
M. microphylla Bickl.	1	–	–	–
M. macroura Miq.	1	–	–	–
M. multicaulis s Perr.	–	–	15	–
Morus spp. (unknown)	15	–	106	259
Total	1375	1860		614

In China, India, Japan, Korea, and Vietnam, there are several germplasm accessions available. More than 1120 germplasm accessions are reported from India. The genetic resources of mulberry are conserved in India through four different techniques: DNA banks, *in vitro* conservation, *ex-situ* conservation, and *in situ* conservation (Manjunath *et al*., 2023). So far about 150 species of genus *Morus* have been described and presently 50% of them have been reduced as synonymous or varieties of the same species. Of late, *Morus* comprises of about 68 recognized species and distributed in different countries mainly from Asian countries like Japan, China, Korea and Taiwan. Continental America is also rich in *Morus* species. Exploration of wild *Morus* species in crop improvement programmes have been greatly thought and major exploration activities in the centers of diversity were undertaken to collect wild species to supplement the genetic variability. *M. multicaulis* species is widely used in many mulberry crop improvement programmes in Japan, India and China (UGC,2024). India has been recognized as one of the twelve mega diversity centers of the world and harboring 11.9% of the world flora. Indian gene centre is very rich in *Morus* species. Wild relatives of genus *Morus* are reported to occur in India in tropical and sub tropical Himalayan belt from Indus to Arunachal Pradesh ascending to 1250 meters. Occurrence of four species of genus *Morus* L. namely *Morus alba, Morus indica, Morus laevigata* and *Morus serrata*. Occurrence of *Morus laevigata* from Andaman and Nicobar Islands. Three species from Assam and Northeast *viz*., *Morus serrata, Morus laevigata* and *Morus acidosa*. Occurrence of *Morus serrata* from Himalayas up to an altitude of 3300 m. Rich *Morus* diversity also exists under both natural and managed habitats. Many foreign rulers introduced many exotic varieties in the Indian gene centre. Besides, the introduced germplasm resources from different temperate and tropical countries, which are available in the research institutes, universities and state departments, are collected to enrich the mulberry gene bank (UGC, 2024).

Objectives of breeding: The primary breeding objectives in India are high leaf yield per unit area, good leaf quality for successful silkworm rearing, resistance to one or many local adverse conditions, *i.e.,* alkalinity, drought, disease, early sprouting and late hardening of leaves, adaptability to a wide range of soil and climate, and good rooting ability (Manjunath *et al*., 2023).

Conventional breeding: A highly precise process is followed by the traditional breeding method that has been utilized to improve the genetics of mulberries. Prior to parental selection, morphological, biochemical, and physiological traits such as stem cuttings' capacity to root, leaf yield, leaf moisture, protein and sugar contents, photosynthetic efficiency, physiological water usage efficiency, and others are used to characterize germplasm accessions. Parents with the required features are chosen by controlled hybridization, and statistical analysis is carried out. For harvesting of seeds for breeding, ripe fruits from both controlled and natural hybridization of chosen mother plants are gathered. In progeny row trials (PRT), seedlings cultivated in nurseries are transplanted to the field for first screening based on chosen features like growth, branching, leaf texture, and disease.susceptibility. Traditional breeding techniques primarily rely on creating F1 hybrids because nearly all mulberry accessions are highly heterozygous and have a long gestation time. The progeny row trial identifies hybrids with desired features, further assessed in the primary yield trial (PYT) for important agronomic, biochemical, and silkworm-feeding properties. The top 5-10% hybrids from the PYT are chosen for detailed evaluation in the final yield experiment (FYT), which uses 3-5 replications and 25-49 plants per replication (Manjunath *et al.,* 2023).

The conventional breeding technique that has been used for mulberry genetic improvement follows a very specific procedure. Prior to parental selection, the characterization of germplasm accessions is carried out using morphological, biochemical and physiological characters, rooting ability of stem cuttings, leaf yield, leaf moisture, protein and sugar contents, photosynthetic efficiency, physiological water use efficiency. Based on a statistical assessment, parents with desired traits are selected and control hybridization is affected. Ripe fruits from controlled hybridization as well as those formed by natural hybridization of selected mother plants are collected to extract seeds. Seedlings raised in a nursery are transplanted to the field in progeny row trials (PRT) for initial screening based on selected traits like growth, branching, leaf texture, and disease susceptibility. Since almost all mulberry accessions are highly heterozygous and have a long gestation period, traditional breeding methodologies mostly rely on the production of F_1 hybrids. Hybrids with desirable traits, identified through the progeny row trial, are further evaluated in primary yield trial (PYT) for important agronomic, biochemical and silkworm feeding qualities. From the PYT, the top 5–10% hybrids are selected for detail assessment in final yield trial (FYT) using 3–5 replications and 25–49 plants per replication. Here, the plants are subjected to thorough assessment for leaf yield, leaf quality, adaptation, susceptibility to pest and diseases, rooting ability, response to agronomic practices, and silkworm feeding qualities. The best hybrid is selected and mass multiplied vegetatively for further testing at different regions (MLT) (Vijayan *et al.,* 2012).

In this chapter, the conventional breeding approaches like introduction, selection from locally available natural populations, selection from open-pollinated hybrid populations, controlled cross-breeding (hybridization), seed complex breeding, mutation breeding and polyploidy breeding followed by systematic screening and rigorous evaluation methods have been discussed (Mogili *et al*., 2023). Further, the importance of available genetic variability, the traits contributing to high leaf yield and quality, parental selection, induction of ploidy, induction of mutation, and isolation of mutants and polyploids by cutback method, screening and evaluation of test genotypes at different stages of varietal development have been emphasized (Mogili *et al*., 2023).

Breeding Methods

It takes many years (approximately 15-20) to develop a new variety of mulberry because it is a perennial woody plant. Breeding targets should be set with a long-term view. To date, breeding targets have been, for example, high yield, high nutritional value and resistance against diseases and pests. But today, new targets have been added to cope with changes in the sericultural system, such as large numbers of silkworm reared and adaptability to densely planted fields suitable for mechanical harvesting (Machii *et al*.,1985). Crossing is the major breeding method adopted for the development of new mulberry varieties. The choice of parent selection plays a vital role in achieving the objective. For example, the variety "Shin-ichinose" was selected from the F1 generation of "Ichinose" x "Kokuso 21". The aim was to develop a variety with high quality, high yield and resistance against lodging from "Ichinose" (good quality and high yield), and "Kokuso 21" (vigorous growth and erect type). Two other varieties, "Tokiyutaka" and "Oyutaka" were also developed and released from this crossing. "Ichinose" (female) and "Kokuso 21" (male) have been used as parents for other varieties. They have desirable traits, and crossing is easy and simple (Machii *et al*.,1985). Many indigenous, natural triploid varieties, such as "Ichibei", "Fukushima Oha", "Akagi" and "Tagowase" have been distributed, especially in the Tohoku area, northern Japan. Since the 1960s, polyploidy breeding has been produced artificially by colchicine, which is capable of doubling chromosome numbers (Machii *et al.,*1985). The significance of polyploidy breeding is that the leaves of triploids are larger than diploids and the yield is higher; crossing between different ploids accumulates more genes than crossing between diploids, and is expected to have more heterotic effect; triploids show good leaf quality and resistance to coldness. To date, five triploid varieties, "Shinkenmochi", "Aobanezumi", "Mitsushigeri", "Yukimasari" and "Yukiasahi" have been developed and released using the polyploid breeding method (Machii *et al*.,1985).

Fruiting Habit: In South India, fruits are observed in two seasons a year: during October-November and during March-May. However, whenever mulberry is pruned or defoliate flowering takes place together with sprouting of auxiliary buds followed by fruit formation. This feature of mulberry is utilized in mulberry breeding programmes. The immature fruits are green in colour but change to purplish to violet black. In certain species such as *M. alba* the fruits are white to pinkish and very sweet. In *M. laevigata* the fruits are very long, sometimes measuring up to 18 cm (Datta, 2024).

Harvesting: There are various training forms in mulberry cultivation according to the various purposes. Maintenance of stump height is one of the typical forms of training. Based on the height from the soil surface: low cut (at the height of 15-30 cm from soil surface), medium low cut (30-50 cm) and medium cut (50-100 cm) are under practice. The second is a fist shape training method: if the plant is pruned at the fold each time, a fist is formed, from where the shoots emerge. Yet, if it is pruned slightly above it, leaving a definite bud, the plant height goes up gradually and a fist is not formed. This is called a non-fist shape training method. The third is a lateral branch training method developed in the Yamanashi prefecture: branches adjacent to plants within a row are held down and tied up with a wire and the shoots emerge from the buds of the branches lying down (Machii *et al.,* 1985). Harvesting methods vary with rearing scale and frequency. Basically there are two methods: spring pruning (for the summer-autumn rearing season) and summer pruning (for both spring rearing and late autumn rearing seasons). There are also the circle harvesting method (spring pruning and summer pruning alternately every year) and alternate harvesting method (alternating spring and summer pruning to half of the same plant). These two methods are adopted to secure enough yield by sustaining the tree vigour. Meanwhile, in densely planted fields, mechanical harvesting is so essential that low pruning, at a point near the ground to prevent stump formation, is desirable (Machii *et al*.,1985). The growth of mulberry is generally divided into three stages: new shoot development, growth and storage. New shoot development is a stage in which new shoots develop using reserves stored in the stump or root the previous year. The growth stage is when carbohydrates and other substances are produced for vegetative growth by means of photosynthesis in leaves. The storage stage is when most photosynthetic substances are stored for the following year's growth. In cultivated mulberry plants, however, photosynthetic organs are removed/harvested by pruning and leaf picking, disrupting the growth stage. The exploited mulberry plants resume growth using the remaining storage substances (Machii *et al*., 1985).

Fresh leaf yield is very variable and depends on the age of the trees and more specifically on the diameter of the trunk: fresh leaf yield ranged from 6.5 to 33.5 t/ha in Spain between the first and the 7th year of growth. In France, 17 t/ha were reported and it was 20 t/ha in Paraguay in a 4-year old plantation harvested at 30 cm from the ground . In Cuba, DM forage yield as high as 10 and 12 t/ha/year were reported. In Uganda, DM leaf yield was near 19 t/ha/year for foliage cut at 2 or 6 months intervals. The nutritive value was the highest at short cutting intervals (Heuzé *et al*., 2019). Mulberry leaf is used as a feed for silkworm. Hence, leaf is to be harvested from the mulberry plant. You shall learn about the leaf harvesting for bush and dwarf plantation and for tree type. Under sub-tropical conditions, individual leaf picking is suggested. However, shoot harvesting could also be followed during final stage of spring rearing. You must keep in mind that harvesting of shoots should not be encouraged during autumn rearing. This will affect subsequent spring leaf production (eGyankosh, 2024). Our focus here would be to know about the leaf harvesting methods for tree type of plantation. You have learnt that the existing system of mulberry plantation available with the farmers in this region is the tree type. It is simple to visualize that harvesting the leaf from trees is a difficult operation. It may not be practically possible and economically viable to pick the leaf individually. Hence, with tree type of plantation, shoots are harvested and this takes care of pruning as well. The shoots are then transported to the rearing rooms and fed to the silkworms. In short, the pruning operation and harvesting of leaf are clubbed together for its practical utility in the field. This method saves a lot of labour and is less time consuming which otherwise is a constraint in the sericulture occupation (eGyankosh, 2024).

Propagation: Mulberry propagation is generally carried out by grafting and by cutting methods. Root grafting prevails because it is easy to handle and the grafted saplings have a high survivability. The cutting method can be with hard wood (using the branches grown in the previous year) and soft wood (using the spring sprouted shoots). With mulberry varieties of poor rooting ability, treatment with plant hormones is advised to stimulate rooting. Recently, tissue culture derived saplings have also been produced (Machii *et al*., 1985). Mulberry trees can be propagated from seeds, cuttings or by grafting. Seeds should be collected from ripe fruits and removed by macerating the fruit in a water bath. Seeds which sink to the bottom of the bath are viable and can be planted immediately or dried and cold stored for planting later. Trees grown from seed can take 10 years or more to produce fruit. Cuttings can be taken during regular pruning of the tree. Branches should be 22 to 30 cm in length and possess a minimum of three buds. Cuttings should be planted immediately. Grafted plants produce stronger root systems than trees produced by any other method of propagation. Grafting is usually achieved by budding in the Spring (Plantvillage, 2024).

Nutritive Value of Leaves: The silkworm eats only mulberry leaves to make its cocoon, producing silk. Mulberry leaves are rich in protein and amino acids. It is known that there is high correlation between leaf protein level and production efficiency of cocoon shell, which means the cocoon shell weight to the total amount of mulberry leaves consumed by the silkworm. Therefore, an increase in the protein level of mulberry leaves may lead to improvements in cocoon productivity (Machii *et al*.,1985).

Taste of Mulberry

If one finds blackberries too sour, they will likely think the same of mulberries. These rich, purple fruits are also one of the most tart berries. Mulberries have mild acidity and varying degrees of sweetness. The fruit's ratio of sweet to tart is difficult to predict: It varies greatly between batches, and the fruits from some seasons taste better than others. White mulberry's flavor is more subdued than its purple counterparts: Indeed, it has less of a bite and tends not to be as sour. In this regard, the flavor differences between mulberry varieties resemble the differences between white and yellow peaches. Though white mulberries are usually sweeter, this also comes at the expense of robustness and a more interesting flavour (Earth of India, 2013).

Toxicity: All parts of the plant besides the ripe fruit contain a toxic milky sap. Eating too many berries may have a laxative effect. Additionally, unripe green fruit may cause nausea, cramps, and a hallucinogenic effect (Wikipedia, 2024).

Varieties: Mulberry varieties released (Saratchandra *et al*., 2011) are given in Table 4 .

Table 4. Varieties authorized

Variety	Regions/Zones	Cultural condition
S1635	Karnataka, Andhra Pradesh, Tamil Nadu, Maharashtra, West Bengal, Uttar Pradesh, Bihar, Assam and other states in Central India	Irrigated
DD	Karnataka, Andhra Pradesh, Tamil Nadu, Maharashtra and Kerala	Irrigated
S36	Karnataka, Andhra Pradesh, Tamil Nadu and Kerala	Irrigated
S1	West Bengal, Uttar Pradesh, Bihar, Assam and Central India	Irrigated, rain-fed
S799	Sericultural regions in central India	Irrigated
S13	Red soil of Karnataka, Andhra Pradesh, Tamil Nadu	Rain-fed
S34	Black soils of Karnataka, Andhra Pradesh, Tamil Nadu	Rain-fed
$BC_2$59	Hilly eastern areas of India	Rain-fed
S146	Central India, Doon valley, Himachal Pradesh and Hilly eastern areas of India	Rain-fed
Tr-10	Central India, West-North Jammu, Doon Valley, Himachal Pradesh and Hilly Eastern areas of India	Rain-fed
Chak Majra	Western North India, Jammu and Himachal Pradesh	Rain-fed
Chinese White	Western North India, Jammu and Western Himachal Pradesh	Rain-fed

The details of improved varieties are given in Table 5 (Manjunath *et al*., 2023).

Table 5. Detailed description of mulberry varieties

Varieties	Characteristics
Victory1 (V1) Selection from a hybrid of S-30 and Ber	1) Erect branching habit, Thick, Succulent, smooth, glossy, ovate, and truncate base. 2) Good rooting ability, superior in yield.
S36	1) Short internodes, semi-erect habit, unlobed, glossy, pale green with a smooth surface. 2) High moisture and high nutrient quality of leaves. 3) suitable for chawki rearing
S 13 Selection from hybrid Kanva-2	1) Short internodes, high branching habit, leaves are thick, unlobed, pale green with a smooth surface. 2) Recommended for rainfed areas and can withstand water scares conditions.
S 34 A hybrid between S-30 and Ber	1) Leaves are medium to large in size, unlobed, and suitable under rainfed conditions. 2) Fast-growing, Deep root system, resistant to water stress conditions and good water retention capacity.
Sahana A hybrid between K-2 and Kosan	1) Short internodes, medium branching, fast-growing, large, thick, glossy, and dark green leaves. 2) Suitable for intercropping with coconut, it performs under limited shade.
Resource Constraint (RC-1) A hybrid between Punjab local and Kosan	1) Short internodes, medium branching habit, slightly spreading habit, leaves are thick, glossy and dark green. 2) Grow well under reduced irrigation and fertilizer condition.
Resource Constraint (RC-2) A hybrid between Punjab local and Kosan	1) Short internodes, fast-growing, slightly spreading, leaves are thick, unlobed, dark green, and glossy. 2) Grow well under reduced irrigation and fertilizer conditions.
AR12	1) Short internodes, medium branching, leaves are unlobed, thick, slightly rough surface.
A hybrid between S-41 (4x) and Ber	2) High rooting ability even under alkaline conditions.
G2 Selection from hybrids of *M. multicaulisin* and S-34	1) Leaves are smooth, glossy and dark green in color. 2) Best suitable for chowki gardens.
G4 Selection from hybrids of *M. multicaulisin* and S-34	1) Short internodes, fast-growing, straight branches, and leaves are thick and wavy margins. 2) Suitable for late-age silkworms.
Vishwa	1) Developed by selection 2) Recommended for irrigated conditions
Vishala	1) Developed by selection 2) Six harvests can be taken per year, with good moisture retention capacity
Suvarna 2 & Suvarna 3	1) Developed by selection 2) Good moisture retention capacity, Recommended for irrigated conditions

Source: (Central Sericultural Research & Training Institute, Mysore, Karnataka; Karnataka state sericulture research and development institute)

V1 and S36 are the high yielding mulberry varieties highly suitable for silkworm rearing. These two varieties produce nutritive leaf, which is essential for good growth of silkworm larvae. The characteristics of these two mulberry varieties are as follows (Mohan *et al*., 2024):

S-36: The leaves are heart shaped, thick and light green with glowing nature. The leaves have high moisture and more nutrient content. About 15,000 to 18,000 Kg of mulberry leaf per year from one acre

V-1: This variety was released during 1997 and very popular in the field. The leaves are oval, broad in shape, thick, succulent and dark green. About 20,000 to 24,000 Kg of mulberry leaf yield can be obtained in a year.

The important species which are cultivated for food are *Morus alba* Linn, *M. indica* Linn. *M. lavogata* Wall., *M. bombycis* Koidz. are widely available, while *Morus australis* Poir and *Morus aciosa* Griff. are endemic to this region. In addition, a number of improved cultivars of mulberry have been evolved by the Research Institutes of Central Silk Board, which are found to be popular in the field. Among these, mention may be made of V1, Kanva-2, S1, S799, TR10, BC259 and S54. Some improved cultivars from Japan and other countries have also been introduced in India with encouraging results. Some of these are Ichinose, Goshoeorami, Kosen (Japan) and Limoncine (Italy) (GOA, 2024).

The recommended varieties are as follows:

Victory 1: It is popularly known as V1. It is a selection from controlled pollinated hybrids of S-30 and Ber. C-776 during late 1990's. The variety is characterized by erect branches and greyinsh stem colour. Leaves are thick, succulent, large, entire and ovate with truncate base. Leaves are smooth and glossy. It has got good agronomic characters like high rooting ability, fast growth and high yiled. Under irrigated conditions, with recommended package of pratices it yields about 60 mt/ha/year. Bioassay and chemoassay tests indicated the superiority of this variety for silkworm rearing (IMV, 2024).

S36: The variety is charactrized by having short inter-nodes, semi-erect habit, medium branching, greyish pink coloured stem. Leaves are unlobed, cordate, glossy, pale-green with smooth surface, with recommended package of practices, it yields 35 - 45 mt/ha/year under irrigated conditions. Because of its high succulance and nutritive quality, it is recommended for youg age silkworm rearing (IMV, 2024).

S13: Mulberry variety S-13 is a selection from open pollinated hybrids of Kanva-2 during 1986. The variety is characterized by short internodes and having a cpacity to produce large number of branches. Leaves are thick and green, unlobed with smooth surface. This variety is recommended for rainfed areas with red loamy soils and also for water scarce areas of Andhra Pradesh ahving high temperature. It yields 12 – 15 mt/ ha/ year under rainfed conditions (IMV, 2024).

S34: The variety S-34 is evolved from cross-pollinated hybrids of S-30 and Ber. C-776 during 1986. The variety is fast growing has deep and extensive root system and it adopts well under soil moisture stress conditions. Leaves are medium to large, unlobed and dark green in colour with high moisture content and good retention capacity. It yields about 12 – 15 mt/ ha/ year under rainfed conditions. The variety is recommended for black cotton soils (IMV, 2024).

Sahana: Sahana is evolved from cross-pollinated hybrids of K2 x Kosen during 2000. It is charactrized by medium branching, fast growing, slightly spreading, pinkish-grey brnaches with short internodes. Leaves are large, unlobed, thick, cordate, glossy and dark green. The variety performs well under limited shade with improved leaf area. As intercrop with coconut plantation (Coconut trees of > 25 years old planted at 8 meters apart) the variety can produce 25 – 30 mt leaf / ha/ year with recommended package of practices under irrigated conditions (IMV, 2024).

RC1 (Resource constraint-1): The variety is evolved from cross-pollinated hybrids of Punjab local x Kosen during 2005. It is a fast growing, medium branching, slighlty spreading pinkish branches with short internodes. Leaves are large, predominantly lobed, thick, cordate, glossy and dark green. The variety performs well even under reduced fertilizer and irrigation. It can yield about 23 – 25 mt leaf / ha/ year with 50% of irrigation and fertilizers recommended for irrigated conditions. Under optimal conditions, it has yield potential of 45 – 50 mt/ ha/ year (IMV, 2024).

RC2: (Resource constraint-2): The variety is evolved from cross-pollinated hybrids of Punjab local x Kosen during 2005. It is a fast growing, medium branching, slighlty spreading pinkish branches with short internodes. Leaves are large, predominantly unlobed, thick, cordate, glossy and dark green. The variety performs well even under reduced fertilizer and irrigation. It can yield about 21 – 23 mt/ ha/ year with 50% irrigation and fertilizers recommended for irrigated conditions. Under optimal conditions, it has an yield potential of 45 – 50 mt/ ha/year (IMV, 2024).

AR12 (Alkalaine tolerant): AR12 is evolved from cross-pollinated hybrids of S-41 (4x) x Ber. C-776 during 2000. It is a fast growing mulberry variety with high rooting ability even under alkaline soils. Bushes are slightly spreading, medium branching, greyinsh with short internodes. Leaves are unlobed, large, cordate, thick, dark green with slightly rough surface. The variety is suitable for alkaline soils with pH range of 8.0 – 9.4 with an yiled potentiality of about 25 mt/ ha/ year in alkaline soils under irrigated conditions with recommended package of practices (IMV, 2024).

G2: The variety G-2 was developed during 2003, it is a selection from controlled pollinated hybrids of M.multicaulis and S-34. The variety is characterised by large, entire, cordate leaves with smooth, glossy. Dark green and slightly wavy margin. It yields 36-38 Mt/ha/year chawki leaves in 8 crops schedul/yr (alternative leaf picking and shoot-let harvest). The variety is most suited for young age silkworm rearing and isrecommanded raising exclusivel chawki gardens (IMV, 2024).

G4: The variety was developed during 2003 from cross pollinated hybrids of M. Multicaulis and S-30. The variety is characterized by open type bushes, fast growing and high branching. Branches are straight, greyish with short inter-nodes. Leaves are dark

green, unlobed, cordate, thick with wavy surface. It has high rooting ability. Under assured irrigation and recommended package of practices it yields 65 mt/ha/year. The variety is recommended for late age silkworm (IMV, 2024).

Though mulberry cultivation is practised in various climates, the major area is in the tropical zone covering Karnataka, Andhra Pradesh and Tamil Nadu states, with about 90 percent. In the sub-tropical zone, West Bengal, Himachal Pradesh and the Northeastern states have major areas under mulberry cultivation. The details of the mulberry varieties under cultivation in different states of India is given in Table 6 (Datta, 2024).

Table 6.Varieties in India

Variety	Region	Developed at	Origin
Kanva-2	South India Irrigated	CSRTI, Mysore	Selection from natural variability
S-36	South India Irrigated	CSRTI, Mysore	Developed through EMS treatment of Berhampore Local
S-54	South India Irrigated	CSRTI, Mysore	Developed through EMS treatment of Berhampore Local
Victoria-1	South India Irrigated	CSRTI, Mysore	Hybrid from S30 x Berc 776
DD	South India Irrigated	KSSRDI, Thalaghattapura	Clonal selection
S-13	South India Rainfed	CSRTI, Mysore	Selection from polycross (mixed pollen) progeny
S-34	South India Rainfed	CSRTI, Mysore	Selection from polycross (mixed pollen) progeny
MR-2	South India Rainfed	CSRTI, Mysore	Selection from open pollinated hybrids.
S-1	Eastern and NE India Irrigated	CSRTI, Berhampore	Introduction from (Mandalaya) Myanmar
S-7999	Eastern and NE India Irrigated	CSRTI, Berhampore	Selection from open pollinated hybrids
S-1635	Eastern and NE India Irrigated	CSRTI, Berhampore	Triploid selection
S-146	N. India and Hills of J and K Irrigated	CSRTI, Berhampore	Selection from open pollinated hybrids
Tr-10	Hills of Eastern India	CSRTI, Berhampore	Triploid of Ber. S1
BC-259	Hills of Eastern India	CSRTI, Berhampore	Back crossing of hybrid of Matigare local x Kosen with Kosen twice
Goshoerami	Temperate	CSRTI, Pampore	Introduction from Japan.
Chak Majra	Subtemperate	RSRS, Jammu	Selection from natural variability
China White	Temperate	CSRTI, Pampore	Clonal selection

Uses

As the fruit matures, mulberries change in texture and color, becoming succulent, plump, and juicy, resembling a blackberry. The color of the fruit does not distinguish the mulberry species, as mulberries may be white, lavender or black in color. White mulberry fruits are typically sweet, but not tart, while red mulberries are usually deep red, sweet, and juicy. Black mulberries are large and juicy, with balanced sweetness and tartness (Wikipedia, 2024). The fruit of the East Asian white mulberry – a species extensively naturalized in urban regions of eastern North America – has a different flavor, sometimes characterized as refreshing and a little tart, with a bit of gumminess to it and a hint of vanilla. In North America, the white mulberry is considered an invasive exotic and has taken over extensive tracts from native plant species, including the red mulberry (Wikipedia, 2024). Mulberries are used in pies, tarts, wines, cordials, and herbal teas. The fruit of the black mulberry (native to southwest Asia) and the red mulberry (native to eastern North America) have distinct flavors likened to 'fireworks in the mouth'. Jams and sherbets are often made from the fruit in the Old World (Wikipedia, 2024). The tender twigs are semisweet and can be eaten raw or cooked (Wikipedia, 2024). Mulberry leaves, particularly those of the white mulberry, are ecologically important as the sole food source of the silkworm (*Bombyx mori*, named after the mulberry genus *Morus*), the cocoon of which is used to make silk. The wild silk moth also eats mulberry. Other Lepidoptera larvae—which include the common emerald, lime hawk-moth, sycamore moth, and fall webworm—also eat the plant (Wikipedia, 2024). The Ancient Greeks and Romans cultivated the mulberry for silkworms; at least as early as 220 AD, Emperor Elagabalus wore a silk robe. English clergy wore silk vestments from about 1500 onwards. Mulberry and the silk industry played a role in colonial Virginia (Wikipedia, 2024). Mulberry fruit color derives from anthocyanins, which have unknown effects in humans. Anthocyanins are responsible for the attractive colors of fresh plant foods, including orange, red, purple, black, and blue. These colors are water-soluble and easily extractable, yielding natural food colorants. Due to a growing demand for natural food colorants, they have numerous applications in the food industry (Wikipedia, 2024). A cheap and industrially feasible method has been developed to extract anthocyanins from mulberry fruit that could be used as a fabric dye or food colorant of high color value (above 100). Scientists found that, of 31 Chinese mulberry cultivars tested, the total anthocyanin yield varied from 148 to 2725 mg/L of fruit juice. Sugars, acids, and vitamins of the fruit remained intact in the residual juice after removal of the anthocyanins, indicating that the juice may be used for other food products (Wikipedia, 2024). During the Angkorian age of the Khmer Empire of Southeast Asia, monks at Buddhist temples made paper from the bark of mulberry trees. The paper was used to make books, known as *kraing*. Tengujo is the thinnest paper in the world. It is produced in Japan and made with kozo (stems of mulberry trees). Traditional Japanese washi paper is often created from parts of the mulberry tree (Wikipedia, 2024). The wood of mulberry trees is used for barrel aging of Țuică, a traditional Romanian plum brandy (Wikipedia, 2024). According to 1 Maccabees, the Seleucids used the "blood of grapes and mulberries" to provoke their war elephants in preparation for battle against Jewish rebels (Wikipedia, 2024).

White mulberry is chiefly used to rear silkworm for silk production. Its foliage can be used as a source of fodder for livestock. The leaves and stems can be cooked as a vegetable. The fruits are edible and can be eaten raw or dried and used as a raisin substitutes. The fruits can be made into juice and beverages. In India, the fruits are traditionally used for dyeing wool in red or purple colour. The bark and wood have been used for centuries for tannery and paper fabrication. The white mulberry provides several environmental services (see below) and is used as an ornamental, in gardens and along roadsides and avenues. Many parts of white mulberry are used in ethnomedicine (Heuzé *et al*., 2019). In China, mulberry trees are part of a millenial circular economy system including the mulberry trees, silk production, fish farming, agriculture and livestock farming: the silkworms feed on the leaves and

the silkworm pupae are fed to fish. The silkworm faeces and the wastewater from silk processing are used to fertilize fish ponds while pond silt makes a good fertilizer for fodder crops that, in turn, are fed to livestock (Heuzé *et al*., 2019). The ripe fruit is edible and widely used in pies, tarts, wines and tea. The fruit of the black mulberry, native to southwest Asia and red mulberry, native to eastern North America have the strongest flavor. The fruits and leaves are sold in various forms as nutritional supplements. Unripe fruit and green parts of the plant have a white sap that is intoxicating. Mulberry leaves, particularly those of white mulberry, are ecologically important as the sole food source of the silkworm, the pupa/cocoon of which is used to make silk. Anthocyanins are pigments which hold potential use as dietary modulators of mechanisms for various diseases and as natural food colorants. Due to increasing demand for food colorants, their significance in the food industry is increasing. Anthocyanins are responsible for the attractive colours of fresh food plants, producing colors such as orange, purple, black and blue. They are water soluble and easily extractable. Mulberry- the sole food plant of Silk worm is grown in India since time immemorial. In addition to feeding silkworm, the leaves have greater potentiality for treating various ailments (UGC,2024). Mulberries can be eaten fresh or used as fillings for tarts and pies. The fruit may also be used to make jams and jellies. They have been traditionally planted as a food source for silk worms (Plantvillage, 2024).

Medicinal uses: The various parts of the mulberry plant find use in Ayurvedic preparations. The leaves have diaphoretic and emollient effects and are used for making a decoction that can be used as a gargle that throat inflammation. The fruits are used to treat sore throat, depression, high fever and are both a coolant and laxative. The root extract has hypoglycaemic properties. The root bark is used as an anthelmintic, purgative and vermifuge. Mulberry root juice is administered to patients with high blood pressure. The Chinese use the leaf tips from young leaves to boil with tea to control blood pressure. The milky latex is used as a plaster for sores and for the preparation of dermal creams (Datta, 2024).

Other Uses: Mulberry was originally cultivated in Japan and other countries for sericulture. Recently, however, mulberry has been re-evaluated because of its functional characteristics and is being utilized for various purposes, such as the following (Machii *et al*.,1985):

Fruit: Mulberry fruit changes colour from green to purple black through red with maturity. Some varieties introduced from mid-Asia have white fruit. On average, the sugar content is about 12 percent, but in some varieties it is more than 20 percent. Mulberry fruit is consumed fresh, made into jam or liquor (mulberry wine). Very recently, it was found that mulberry fruit has an anti-oxidative property (Machii *et al*.,1985).

Medicinal uses: Mulberry has been used as a medicine from ancient times. The root bark in particular has been used as a herbal medicine to reduce high blood pressure. Mulberry leaf is rich in gamma-aminobutylic acid, effective against high blood pressure, and in alanine, effective against hangovers (Machii, 1989, 1990). Moreover, it has been found that deoxynojirimycin, which is said to have an effect in lowering the blood-sugar level closely related to diabetes, is abundant in mulberry leaf. That is why, today, mulberry tea is considered to be a health food (Machii *et al*.,1985).

Paper production: Mulberry grows more quickly than other woody plants and is said to be suitable for high biomass production. Mulberry branches are being used as raw material for paper production (Machii *et al.*,1985).

Mushroom production: Mulberry stem and stem powder are found to be a good source of media for mushroom production (Machii *et al*.,1985).

Animal feed: The use of mulberry for animal production in Japan is being reported in other articles in this E-conference (Machii *et al*.,1985).

Health Benefits

Mulberries are loaded with health benefits on account of its deep purple hue. Dark-skinned fruits—like cherries, pomegranates, grapes, and blueberries—have cancer-fighting polyphenols. Mulberries are no exception. Traditionally, Ayurvedic practitioners have used mulberry leaves as an emollient and diaphoretic**,** and the fruits to treat depression and fever. To combat sore throats, some gargle a brew created from the leaves. According to the book, "Invasive Plant Medicine," white mulberry leaves treat fever**,** headache, dry eyes**,** and vertigo**;** and the bark treats wheezing, irritability**,** and facial swelling**.** The fruit itself is believed to be a remedy against constipation, premature aging, insomnia and tinnitus (Earth of India, 2013). The scientific community has found incredibly promising health benefits for *Morus* fruits as well:

- Scientists in India published a study in *Dovepress* revealing *Morus indica's* ability to decrease blood sugar levels and liver glycogen levels, thus illustrating antidiabetic and antioxidant potential.
- A 2012 study published in *Life Sciences* found that white mulberry has potent anti-ulcer compounds
- As per a study published in *International Journal of Biological Sciences,* the flavonoids found in white mulberry leaves combatted oxidative stress and cell death responsible for problems like hypo-cholesterol**,** hypoglycemia and cataract formation.
- Another study published in by the "International Journal of Diabetes in Developing Countries" affirmed the cholesterol lowering potential of white mulberry leaves
- A study published in "The Journal of Nutritional Biochemistry" found that the anthocyanins in mulberries boost memory and may stave off Alzheimer's disease (Earth of India, 2013).

Pests of mulberry (Datta, 2024).

Maconellicoccus hirsutus (mealy bug) - causing tukra in mulberry *Diaphania pulverulentalis* - Leaf roller *Spilarctia obliqua* - Bihar hairy caterpillar (sporadic pest)

Diseases of mulberry (Datta, 2024).

Foliar. Leaf spot, leaf rust, powdery mildew, leaf blight and bacterial blight Soilborne. Root rot and root knot Nursery diseases. Stem canker, cutting rot, collar rot and dieback

Storage: Keep mulberries in the cool, dry part of the fridge, where they should keep for a day or two. Avoid leaving the fruits at room temperature, as they'll mold quickly, and wash mulberries only before consuming. It is possible to freeze mulberries: simply spread on a baker's tray atop parchment, freeze, and then place in a freezer bag. Frozen mulberries keep for a year (Earth of India, 2013).

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