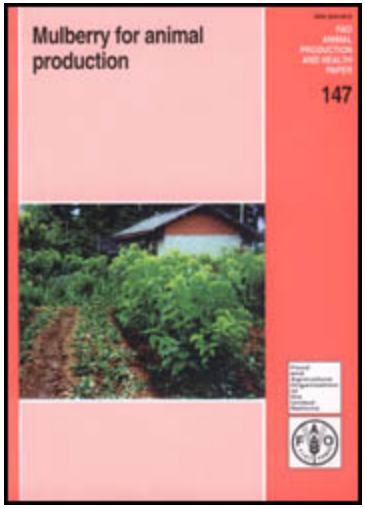
Mulberry for Animal Production



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M. D. Sánchez
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Foreword

Throughout the world the need to intensify and improve the efficiency of livestock production practices in a sustainable manner that reduces the dependency on external inputs, while conserving the natural resource base and promoting biodiversity, has been widely recognized. Demand for animal products in many developing counties is increasing due to population growth, urbanization and economic growth. Recent crises in livestock production, such as bovine spongiform encephalopathy (BSE) which has spread from the United Kingdom throughout Europe, highlights the need to search for alternative, more natural, production systems.

Mulberry, the feed of the silkworm, was one of the first domesticated forages in the world and has been the subject of intensive research in various countries over the last few decades.

This has resulted in higher yields of better quality foliage to be converted into silk.

Where the mulberry grows naturally and where sericulture is well established, its foliage and the production residues (faeces and leftovers) are regularly fed to livestock. However, its intensive cultivation and use specifically for animal production only started during the last two decades.

In response to the growing interest in the utilization of mulberry for animal production, the Animal Production and Health Division of FAO organized the first electronic conference on this subject during 2000. Mulberry and animal production experts from Asia, Europe, Latin America and Africa participated and contributed on a wide range of topics covering genetic resources, agronomy, harvesting, processing, nutritive value and animal performance.

Mulberry is present in countries all over the world and its unique characteristics of yield, palatability and nutritive value make it a valuable resource for improving and intensifying a variety of

livestock production practices.

We hope that this publication contributes to the recognition of the potential of this multipurpose plant and encourages research and development efforts aimed at intensifying sustainable production for the benefit of the rural population and the environment.

Hiroshi Kudo
Chief, Animal Production Service
FAO Animal Production and Health Division

World distribution and utilization of mulberry and its potential for animal feeding

Manuel D. Sánchez
Animal Production Officer
Animal Production and Health Division
FAO, Rome

INTRODUCTION

The scientific name of mulberry is *Morus* spp*.,* a genus belonging to the Moraceae family of the Urticales subclass. Mulberry is usually associated with sericulture, the production of silk through the silkworm (*Bombyx mori*). The domestication of mulberry started several thousands of years ago as a requirement for silkworm rearing (FAO, 1990).

Considering that the silk trade has existed for a long time throughout the Old World and that mulberry is also cultivated for its fruit and for landscaping, its germplasm has been taken to many countries, and it now has a very wide distribution range in Asia and Europe (from Korea to Spain, including China, India, Central Asia and the Near East); in Africa (North and East Africa)

and in the Americas (from the United States to Argentina, including Mexico, Central America, Colombia and Brazil). The origins of most cultivated mulberry varieties are believed to be in the China/Japan area and in the Himalayan foothills.

Silk production was important in Europe during the nineteenth and early twentieth centuries, as it was in Japan and Korea up to the middle of the twentieth century. Silk production nowadays is dominated by China and India.

Although in some countries of Asia mulberry leaves have been traditionally fed to farm animals, interest in the intensive production of mulberry and its utilization for animal production started in several countries in the late 1980s and early 1990s. The attractive biomass yields, palatability and exceptionally high nutritive value for ruminant and monogastric animals have been the reasons behind the great interest in mulberry for animal feeding in recent years.

This introductory paper gives a general framework of mulberry in

the world without going into specific details, which will be covered and discussed in other conference papers.

SPECIES AND VARIETIES OF MULBERRY

There are about 68 species of the genus *Morus*, and the majority of them occur in Asia (Datta, 2000). In China, there are over a thousand varieties under cultivation. They originated from four main species, the White mulberry (*Morus alba*), the Lu mulberry (*M. multicaulis*), the Mountain mulberry (*M. bombycis*) and the Guangdong mulberry (*M. atropurpurea*) (Yongkang, 2000).

In India the main species are *M. indica, M. alba, M. serrata* and *M. laevigata,* which grow naturally in the north of the country (Ravindran *et al*., 1997). Most of the cultivated varieties belong to either *M. indica* or *M. alba*. In Mysore, India, the Central Sericulture Research and Training Institute keeps 244 mulberry cultivars: 78 indigenous, 44 exotic, 21 unknown and 101 elite hybrids (Sastry, 1984).

In the republics of the former Soviet Union, the most common species are *M. multicaulis, M. tartarica* and *M. nigra* (Datta, 2000). In Indonesia (West Java) there are seven species: *M. alba* (varieties *tartanica* and *macrophyla*), *M. nigra, M. multicaulis, M. australis, M. cathyana* and *M. mierovra* (Katsumata, 1972). In Viet Nam there are over 100 varieties, mainly *M. alba, M. nigra* and *M. laevigata* (Katsumata, 1973). According to Janaki Ammal (1960) only *M. rubra* is native to the Americas.

The most popular species in the world are believed to be *M. alba* and *M. indica*. These have been the subject of intensive selection from open pollination, controlled hybridization and selection and mutation breeding in several countries, resulting in over a thousand varieties, including many polyploids. In Brazil there are about 90 varieties, all *M. alba* (de Almeida and Fonseca, 2000).

A key to the taxonomy of mulberry, as proposed by Chinese scientists, is included in the paper on mulberry in China on p.11 (Huo, 2000).

CURRENT USES OF MULBERRY

Sericulture

The most important use of mulberry globally is in the production of silkworm, which feeds exclusively on its leaves. The country with the largest area of mulberry is China with approximately 626 000 ha, then India with nearly 280000 ha. Several other countries, such as Thailand and Brazil (35 000 ha), still have some mulberry production but on a much smaller scale.

Silk projects have been and are being started in various developing countries, particularly in Africa and Latin America. Regardless of how successful or sustainable they have been, these projects have been responsible for the introduction and dissemination of mulberry varieties under different soil and climatic conditions.

Fruit

All throughout Asia, but particularly in Central Asia and in the Near East, mulberry is highly appreciated for its delicious fruit, which is consumed fresh, or in the form of juice or conserves. A few mulberry orchards also exist in Latin America.

Wood

Especially in the Indian subcontinent, mulberry wood is used for handicrafts, cabinet work and for sporting woods (e.g. grass-hockey sticks and tennis rackets). Its thin branches are woven into baskets.

Landscaping

In Asia, southern Europe and in the southern United States, mulberry trees are utilized for landscaping (Tipton, 1994). Their resistance to pruning and their low water requirements make them very suitable plants for urban conditions, house gardens, street shade and city embellishment.

Medicine

A variety of medicinal properties has been attributed to the different parts of the mulberry plant (Datta, 2000). Leaves are also dried and used in infusions in Asia (e.g. China and Thailand).

Forage

Silk producers have traditionally fed mulberry surpluses from silkworm feeding to farm animals and to herbivorous carp in polyculture fish ponds (Gongfu, Zengqi and Houshu, 1997). In this sense, farm animals are well integrated into silk production. There have even been economic studies of the combined benefits from silk and dairy production in India (Mehla, Patel and Tripathi, 1987). A review of mulberry for animal feeding has been published by FAO (FAO, 1999).

In countries south of the Himalayas, where mulberry trees occur in nature, their foliage has been part of the traditional mixed diet of domestic ruminants. In India there have been numerous

research reports on the use of mulberry residues and leaves for various domestic animals, from cows to poultry. In general terms, Indian scientists have considered mulberry foliage as medium-quality forage.

Some small farmers in East Africa, mainly in the United Republic of Tanzania and in Kenya, harvest foliage from mulberry trees and include it as part of the diet offered to ruminants in confinement. Although its nutritive value is recognized in these countries, there has been little planting of mulberry for this purpose.

Since the late 1980s and mainly in the late 1990s, the cultivation of mulberry as forage has expanded considerably in Latin America, in Central America and in the Caribbean in particular, but it is still mainly associated with research institutions. This has been mainly the result of the initial studies carried out by the Tropical Agriculture Research and Higher Education Center (CATIE) in Costa Rica and in other Central American countries (Benavides, 1994) and the expansion by a number of research and development projects. There have been, however, in other

countries in Latin America (e.g. Brazil and Colombia), independent initiatives to feed mulberry leaves to various species of farm animals.

MULBERRY RESEARCH

Beginning in the nineteenth century extensive research on the various components of the cultivation of mulberry has been carried out in several countries, depending on the viability of the local silk industry. A great deal of work took place in several European countries, for example, France, Italy, Bulgaria and Poland. By the middle of the twentieth century, silk production in Europe had practically disappeared. Significant production and research also took place in Japan and Korea in the middle of the twentieth century.

Currently, most of the mulberry research for sericulture takes place in China and India, with several institutions actively involved in both countries. For fruit and for silk production, studies are being carried out in the Central Asian republics of the former

Soviet Union, for example, in Uzbekistan, Turkmenistan, Tajikistan and Kyrgyzstan.

Studies on mulberry as animal feed are being or have been conducted in Japan, India, the United Republic of Tanzania, Kenya, Costa Rica, Colombia, Mexico, El Salvador, Guatemala, Brazil and Cuba. The most active research on mulberry for animal feeding is currently taking place in Cuba. Research includes agronomic aspects, harvesting modalities, forage preservation and animal trials.

POTENTIAL OF MULBERRY FOR ANIMAL PRODUCTION

It is not by chance that mulberry germplasm is causing so much interest as an alternative high-quality feed for farm animals. Over several hundreds, and perhaps thousands, of years, mulberry species and varieties have been selected and improved to feed the silkworm, which is nutritionally very demanding. The aim has been to produce greater quantities of leaves of higher quality under a wide range of conditions (in the tropical, subtropical and

temperate regions).

Although, in general terms, the principles of mulberry cultivation for sericulture purposes should apply to its cultivation as forage for feeding farm animals, there are certain important differences. Frequency of harvesting and, in particular, planting density, can be intensified if the goal is to feed ruminants, since the quality is already high enough and the main purpose is to increase overall biomass yields. The issues of maintenance of soil fertility and plant persistence become important if huge quantities of nutrients are extracted from the soil in the biomass under cut-and-carry systems.

Individual leaf picking, as is commonly practised for silkworm feeding, can only be justified for small-scale or family units of mini-livestock, such as snails, guinea pigs or rabbits. Mechanical harvesting might be more appropriate for ruminant feeding in larger operations.

Feeding ruminants

The urgent need for a high-quality feed for ruminants in the tropics, in particular for small ruminants, and the excellent characteristics of mulberry, are the justifications for the great enthusiasm over its intensive cultivation and use as a feed supplement for cattle, and as the main feed for goats.

The nutritional quality of locally produced mulberry leaves is equivalent to that of grain-based concentrates. Thus, they are an ideal supplement in most forage diets.

The greatest impact of mulberry on livestock productivity is to be expected in the dairy cattle sector in the tropical regions.

Feeding mini-livestock

The nutritive value of mulberry leaves becomes greater in inverse proportion to animal size, since metabolic rate and hence nutrient requirements decrease with size (to the power of 0.75). Mulberry leaves should be the preferred feed for guinea pigs, rabbits and perhaps snails. The performance of dairy goats fed mulberry-

based diets in Costa Rica has been impressive (Oviedo *et al*., 1994). Many more excellent results are to be expected when mulberry is offered to other herbivores, particularly small species.

Mulberry for browsing

Several studies have examined the possibility of mulberry for direct browsing by cattle in Italy (FAO, 1993), in France (Armand and Meuret, 1995) and in Japan (Kitahara, 1999). Although the results have been promising, a great deal of work will need to be done before mulberry is incorporated into grazing systems on a large scale.

The Table summarizes the utilization of and research on mulberry in different parts of the world.

Country summary of mulberry area (1 000ha), use and research

	Country	Area	Utilization		Research	

			Silk	Fruit	Forage	Other*	Agr.	Breed.	Feed
AFRICA	Egypt and Tunisia	n.a.**	Ö	Ö			Ö		
	Ethiopia	n.a.	Ö				Ö		
	Kenya	n.a.	Ö		Ö		Ö		Ö
	Madagascar	n.a.	Ö				Ö		
	Tanzania	n.a.			Ö				Ö
AMERICAS	Argentina and Bolivia	n.a.				Ö[1]			
	Brazil	38	Ö		Ö		Ö	Ö	Ö
	Colombia	n.a.	Ö		Ö		Ö		
	Costa Rica	n.a.			Ö		Ö		Ö
	Cuba	<1			Ö		Ö		Ö
	Dominican Rep.	<1			Ö				
	El Salvador	≤1			Ö				Ö
	Guatemala	n.a.							

	Guatemala	n.a.			Ö				Ö
	Honduras and Panama	<1			Ö				
	Mexico	<1	Ö	Ö	Ö	Ö[1]	Ö		Ö
	Panama	<1			Ö				
	Peru	n.a.				Ö[1]			
	Saint Vincent	<1			Ö				
	United States	n.a.				Ö[1]			Ö
ASIA	Afghanistan	n.a.			Ö				
	China	626	Ö			Ö[2]	Ö	Ö	
	India	280	Ö		Ö	Ö[3]	Ö	Ö	Ö
	Indonesia	n.a.	Ö						
	Japan	n.a.	Ö	Ö	Ö	Ö[2]	Ö	Ö	Ö
	Korea	n.a.	Ö		Ö		Ö	Ö	
	Kyrgyzstan	n.a.	Ö	Ö			Ö		

	Malaysia	n.a.	Ö				Ö		
	Pakistan	n.a.	Ö		Ö		Ö		
	Philippines	n.a.	Ö				Ö		
	Syrian Arab Republic and Turkey	n.a.		Ö					
	Tajikistan	n.a.	Ö				Ö		
	Turkmenistan	n.a.	Ö	Ö			Ö		
	Viet Nam	n.a.	Ö		Ö		Ö	Ö	
	Uzbekistan	n.a.	Ö				Ö		
EUROPE	Bulgaria	n.a.					Ö		
	France	n.a.			Ö	Ö[1]	Ö		Ö
	Greece	n.a.				Ö[1]			
	Italy	n.a.				Ö[1]	Ö		Ö
	Poland	n.a.					Ö		
	Spain	n.a.				Ö[2]			

	Spain	n.a.				O2			

* Other uses: [1]Landscaping and gardening; [2]Medicinal and infusion;

[3] Handicrafts and cabinet work ** n.a. data not available

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Mulberry cultivation and utilization in China

Yongkang Huo
Regional Sericulture Training Centre for Asia and Pacific
South China Agricultural University
Guangzhou, China

AREA CULTIVATED WITH MULBERRY

China is the largest producer of mulberry and silk in the world. In 1998, fresh cocoon production was 432 820 tonnes from 626 000 ha of mulberry. Mulberry is distributed all over the country. The main provinces and autonomous regions with mulberry cultivation and their varieties are described here.

Xinjiang Uygur Autonomous Region

Geographical position. Situated in northwest China.

Climatic features. Continental, dry and sunny. In south Xinjiang, the effective accumulated temperature is higher than 3 500^{O}C, the frostless season is more than 150 days, but the annual rainfall is less than 100 mm.

Main mulberry variety cultivated. He Tian Bai Sang.

Shandong and Hebei Provinces

Geographical position. Situated at the lower end of the Yellow River, these are the main sericulture provinces in north China.

Climatic features. Average daily temperature of 8-15ºC, frostless season 170-250 days, annual rainfall 400-1 000 mm.

Main mulberry varieties cultivated. Da Ji Guan, Hei Lu Cai Sang, Xuan 792 and Niu Gen Sang.

Shanxi and Shaanxi Provinces

Geographical position. Situated at the middle of the Yellow River.

Climatic features. Average temperature 10-14ºC, frostless season 150-200 days, annual rainfall 400-700 mm.

Main mulberry variety cultivated. Hei Ge Lu.

Zhejiang and Jiangsu Provinces

Geographical position. The main sericulture area in China, situated at the end of the Yangtze River.

Climatic features. Average temperature 15-18ºC, frostless season 250-275 days, annual rainfall 1 000-1 500 mm.

Main mulberry varieties cultivated. Tong Xiang Qing, Hong Cang Sang, Hu Sang 197, Hu Sang 199, Huo Sang, Nong Sang 8, Yu 2 and Zhong Sang 5801.

Anhui, Hubei and Hunan Provinces

Geographical position. Situated at the middle of the Yangtze River.

Climatic features. Average temperature 15-20ºC, frostless season 250-300 days, annual rainfall 1 000-1 500 mm.

Main mulberry variety cultivated. Hong Pi Wa Sang.

Sichuan Province

Geographical position. Province with the largest mulberry area in China, situated on the upper Yangtze River.

Climatic features. Average temperature 16-18ºC, frostless season 240-330 days, annual rainfall 1 000-1 250 mm.

Main mulberry varieties cultivated. Hei You Sang, Da Hua Sang, Xiao Guan Sang and Jia Ling 16.

Guangdong and Guangxi Provinces

Geographical position. Situated by the Pearl River in south China, the most subtropical zone.

Climatic features. Average temperature 22ºC, frostless season 340 days, annual rainfall 1 500-2 000 mm.

Main mulberry varieties cultivated. Guangdong Jing Sang, Lun 40, Lun 109, Sha 2, Da 10 and Kang Qing 10.

Yunnan and Guizhou Provinces

Geographical position. Situated in Yun-gui High Plateau of southwest China.

Climatic features. The effective accumulated temperature is higher than 3 500ºC, the frostless season longer than 200 days and annual rainfall above 600 mm.

Main mulberry varieties cultivated. Yun Sang 2 and Dao Zhen

Sang.

TAXONOMY

In China, the scientists classify the genus *Morus* into 14 species and one variety. The key for identification is the following:

Mulberry identification key

1. Pistils with distinct long styles

    1.1. Protuberance within the stigma

        1.1.1. Denticle pick of leaf margin with long prickle

            1.1.1.1. Upper surface of leaf smooth, without hair; lower surface green, with some pubescence, usually non-incised:
            Mongolian mulberry (*M. mongolica*

Schneid)

1.1.1.2. Upper surface of leaf rough; lower surface greyish-white, with dense pubescence, usually incised: **Gui mulberry (*M. mongolica var. diabolica* Koidz)**

1.1.2. Denticle pick of leaf margin without prickle

1.1.2.1. Upper surface of leaf smooth

1.1.2.1.1. Upper surface of leaf non-shrivelled; denticle pick of leaf margin with short protuberance; style as long as stigma; sorosis globular: **Tang-gui mulberry (*M. nigriformis* Koidz)**

1.1.2.1.2. Upper surface of leaf shrivelled; denticle pick of leaf margin without protuberance; style shorter than stigma; sorosis elliptical: **Rui-sui mulberry (*M. mizuho* Hotta)**

1.1.2.2. Upper surface of leaf coarse

1.1.2.2.1. Leaf round or broad-ovate, lower surface without pubescence; sorosis cylindrical, 3-3.5 cm long, jade-white in colour when mature: **Chuan mulberry (*M. notabilis* Schneid)**

1.2. Hair within the stigma

1.2.1. Leaf cordate or ovate, lower surface with scarce pubescence; sorosis elliptical, 2 cm long, purplish-black when mature:
Mountain mulberry (*M. bombycis* Koidz)

1.2.2. Leaf ovate or slant-ovate, usually incised, margin serrated small and dense; style longer than stigma; sorosis 1 -2 cm long, dark purple when mature:
Ji mulberry (*M. australis* Poir.)

1.2.3. Leaf codate or broad codate, usually non-incised, margin serrated triangular with short pick; style shorter than stigma; sorosis 4-6 cm long, red when mature:
Tian mulberry (*M. yunnanensis* Koidz)

2. Pistils without distinct long styles

2.1. Protuberance within the stigma

2.1.1. Leaf hairless or with pubescence in young stage; sorosis narrow-cylindrical, 4-16 cm long

2.1.1.1. Leaf long elliptical, entire leaf margin or with shallow serrates in the upper margin; 3-4 pairs of side veins; mature sorosis purplish-red:
Chang-sui mulberry (*M. wittiorum* Hand-Mazz.)

2.1.1.2. Leaf broad ovate, margin with small serrates; 4-6 pairs of side veins; mature sorosis yellowish-green or purplish-red:
Chang-guo mulberry (*M. laevigata* Wall.)

2.1.2. Hairy leaf veins of lower surface; sorosis elliptical, 1-2.5 cm long

2.1.2.1. Big leaf, usually non-incised, with water-bubble appearance or shrivelled; mature sorosis purplish-black:
Lu mulberry (*M. multicaulis* Perr.)

2.1.2.2. Small leaf, usually incised, surface smooth; mature sorosis purplish-black or jade-white, occasionally pink:
White mulberry (*M. alba* Linn.)

2.2. Hairs within the stigma

2.2.1. Lower leaf surface with pubescence; short petiole; mature sorosis purplish-black or purplish-red.

2.2.1.1. Upper surface of leaf rough; petiole without groove; sorosis

elliptical, 1.5-3 cm long, purplish-black when mature:
Black mulberry (*M. nigra* Linn.)

2.2.1.2. Upper surface of leaf with pubescence; petiole with shallow groove; sorosis cylindrical, two to three cm long, purplish-black or purplish-red when mature:
Hua mulberry (*M. cathayana* Hemsl.)

2.2.2. Lower leaf surface hairless; upper surface usually smooth, less lustre; sorosis narrow-circular cone with round tip, 2-4 cm long, purplish-black when mature:
Guangdong mulberry (*M. atropurpurea* Roxb)

MULBERRY VARIETIES

There are more than 1 000 cultivated varieties of mulberry in China. Most of them originate from the four main species: Lu mulberry (*M. multicaulis* Perr.), White mulberry (*M. alba* L.), Mountain mulberry (*M. bombycis* Koidz) and Guangdong mulberry (*M. atropurpurea* Roxb.).

The main cultivated varieties of mulberry in China are the following.

Tong Xiang Qing

Indigenous and widely distributed in Zhejiang Province. It belongs to the species of Lu mulberry (*M. multicaulis* Perr.). Chromosome number is 2n = 2x = 28.

Morphology. The tree is straight. The twigs are sturdy, long and straight, greenish-grey and somewhat yellow in colour. Internodes are straight. Internodal distance is 4.2 cm. Leaf order is 2/5. Lenticels are small and round, greyish-yellow, 8/cm^2. Winter bud is long triangle, large size, yellowish brown, adhering to the

branch. Accessory buds are abundant and large. Leaf ovate, dark green. Leaf tip is sharp. Leaf margin is papillately dentate. Leaf base retuse. Leaf length is 22.8 cm, width 18.3 cm. Leaf blade is thick. Leaf surface smooth without shrivels, with good lustre. Leaves hang slightly downwards. Petiole is long and sturdy. Flowering type is monoecious. Inflorescences of staminate flowers are few, medium long.

Climatic requirement. Bud sprouting in Hangzhou is from 28 March to 6 April. Leaf-opening stage is in the middle of April. Bud sprouting ratio is 61.5 percent and the bud-growing ratio is 11.1 percent. Leaves mature in early May, belonging to the medium sprouting and mid-mature variety. Autumn leaves harden in mid-September.

Average yield per ha. This variety has medium shooting ability and few side branches. From 1 m shoot, 139 g leaves can be produced in spring and 151 g produced in autumn. There are 260 leaves/kg in spring and 200/kg in autumn. Leaves are 45.4 percent of the total weight of twigs, shoots, leaves and fruits.

Annual leaf yield is 34 500 kg/ha.

Fruiting habits. Few soroses, medium-large size and purplish-black.

Leaf chemical composition. Leaf quality is good. Leaf dry matter (DM) contains 22.0-24.5 percent CP and 15.1 percent SC.

Main diseases/pests and tolerance. This variety has resistance to Shrinking-type mulberry dwarf caused by mycoplasma-like organisms (MLOs) and Brown spot disease caused by the fungi of *Septogloeum mor Briosi et Cavara*. However, it is sensitive to Black wilt bacterial disease caused by *Bacterium mori Boyer et lamb Smith* and Mulberry powdery mildew caused by *Phyllactinia corylea* (Pers) Karst.

Fertilization recommendations: Sufficient water supply and fertilization in summer and autumn are needed for preventing leaves from early hardening.

Hong Cang Sang

Selected from the varieties of Tong Xiang Qing, belonging to the species of Lu mulberry (*M. multicaulis* Perr.). Chromosome number is 2n = 2x = 28. Widely distributed in Zhejiang and Jiangsu Provinces.

Morphology. The canopy is somewhat spreading. The twigs are sturdy, long and straight and purplish-brown in colour. Internodes are comparatively straight. Internodal distance is 4.0 cm. Leaf order is 2/5 or 3/8. Lenticels are nearly round or elliptical, brown, medium size, 8/cm^2. Winter bud is triangle, large, light purplish-brown, slanting outwards. Accessory buds are large but few. Leaf ovate, dark green. Leaf tip is acute. Leaf margin is papillately dentate. Leaf base retuse. Leaf length is 21 cm, width 15.5 cm. Leaf blade is thick. Leaf surface smooth with good lustre. Leaves hang slightly downwards. Petiole is a long and sturdy. Flowering type is monoecious, bearing only or both staminate and pistillate flowers in a separate cluster. Inflorescences of staminate flowers are few, medium long.

Climatic requirement. Bud sprouting in Hangzhou is from 30 March to 6 April. Leaf-opening stage is from 7 to 18 April. Bud sprouting ratio is 55 percent and the bud-growing ratio is 19.8 percent. Leaves mature in early May, belonging to the medium sprouting and mid-mature variety. Autumn leaves harden in mid-September.

Average yield per ha. This variety has medium shooting ability and few side branches. From 1 m shoot, 135 g leaves can be produced in spring and 137 g produced in autumn. There are 263 leaves/kg in spring and 137/kg in autumn. Leaves are 46 percent of the total weight of twigs, shoots, leaves and fruit. Annual leaf yield is 33 900 kg/ha.

Fruiting habits. Few soroses, large size, purplish-black.

Leaf chemical composition. Leaf quality is good. Leaf DM contains 20.6-23.8 percent of CP and 16.9 percent of SC.

Main diseases/pests and tolerance. This variety has resistance to

Mulberry dwarf and Brown spot disease. However, it is sensitive to the bacterial disease caused by *Pseudomonas syringae* Pv. mori Van Hall. It has stronger cold resistance than that of Tong Xiang Qing. Recommended training type is low or medium trunk with higher planting density.

Hu Sang 197

Selected from Zhejiang Province, belonging to the species of Lu mulberry (*M. multicaulis* Perr.). Chromosome number is 2n = 2x = 28.

Morphology. Canopy is spreading. Twigs are sturdy, long and straight, light purplish-brown. Internodes are slightly curved. Internodal distance is 3.8 cm. Leaf order is 2/5. Lenticels are small and elliptical, greyish-brown, 13/cm^2. Winter bud is a long triangle, greyish-brown, adhering to the branch. Accessory buds are few and smaller. Leaf is long-cordate, slightly tilting to one side, dark green in colour. Leaf tip is short-caudate. Leaf margin is papillately dentate. Leaf base emarginate. Leaf length is 24.5

cm, width 19.9 cm. Leaf blade is medium thick. Leaf surface smooth slightly shrivelled, good lustre. Leaves hang slightly downwards. Petiole is long and sturdy. Flowering type is pistillate.

Climatic requirement. Bud sprouting is from 30 March to 6 April. Leaf-opening stage is from 8 to 19 April. Bud sprouting ratio is 70 percent and the bud-growing ratio is 14.3 percent. Leaves mature in early May, belonging to the late-sprouting and mid-mature variety. Autumn leaves harden in late September.

Average yield per ha.This variety has strong shooting ability and the side branches are few. From 1 m shoot, 128 g leaves can be produced in spring and 170 g produced in autumn. There are 375 leaves/kg in spring and 224/kg in autumn Leaves are 47.7 percent of the total weight of twigs, shoots, leaves and fruit. Annual leaf yield is 33 750 kg/ha.

Fruiting habits: Soroses are few and small, purplish-black.

Leaf chemical composition: The leaf quality is good. Leaf DM

contains 18.7-27.1 percent of CP and 13.1 percent of SC.

Main diseases/pests and tolerance. This variety is medium-resistant to Mulberry dwarf and Brown spot disease but sensitive to Black wilt bacterial disease. It has good tolerance to drought and poor fertilization, therefore, it is recommended planting on river- and hillsides, with medium or low trunk.

Hu Sang 199

A resistant variety selected from Zhejiang, belonging to the large-leaf variety of species of White mulberry (*M. alba* L.). Chromosome number is 2n = 2x = 28. Widely cultivated in Zhejiang and Jiangsu Provinces.

Morphology. Canopy is slightly spreading. Twigs are sturdy, long and straight, purplish-brown. Internodes are comparatively straight. Internodal distance is 5 cm. Leaf order is 2/5. Lenticels are nearly round and small, yellowish-brown in colour, 12/cm^2. Winter bud is triangle, purplish-brown, adhering to the branch.

Accessory buds are few and smaller. Leaf is cordate, light green. Shallowly incised leaf is occasionally found. Leaf tip is short-caudate. Leaf margin is obtuse dentate. Leaf base emarginate. Leaf length is 22.9 cm, width 21.5 cm. Leaf blade is comparatively thin. Leaf surface smooth and slightly shrivelled. Leaves hang slightly downwards. Petiole is long and sturdy. Flowering type is monoecious, bearing only or both staminate and pistillate flowers in a separate cluster. Number and length of inflorescences of staminate flowers are medium.

Climatic requirement. Bud sprouting is from 30 March to 6 April. Leaf-opening stage is from 8 to 18 April. Bud sprouting ratio is 75 percent and the bud-growing ratio is 13.4 percent. Leaves mature from 6 to 15 May, belonging to the late-sprouting and late mature variety. Autumn leaves harden in early October.

Average yield per ha. This variety has strong shooting ability. From 1 m shoot, 151 g leaves can be produced in spring and 119 g produced in autumn. There are 400 leaves/kg in spring and 239/kg in autumn. Leaves are 44 percent of the total weight of

twigs, shoots, leaves and fruit. Annual leaf yield is 29 250 kg/ha.

Fruiting habits. Soroses are few but large, purplish-black.

Leaf chemical composition: The leaf quality is comparatively poor. Leaf DM contains 19.8-21.0 percent of CP and 15.3 -16.2 percent of SC.

Main diseases/pests and tolerance. This variety is resistant to Yellow-type mulberry dwarf caused by MLOs and Black wilt bacterial disease. It also has good rooting ability by cutting.

Huo Sang (Fire mulberry)

A native variety of Zhejiang, belonging to the species of Rui-sui mulberry (*M. mizuho* Hotta.). It is a natural triploid, with chromosome number 2n = 3x = 42. Widely distributed in Zhejiang Province.

Morphology. Canopy is spreading. Twigs are sturdy, long and straight, purplish-brown in colour. Internodes are straight.

Internodal distance is 4.6 cm. Leaf order is 2/5 or 3/8. Lenticels are large and round or ellipical, 13 l/cm^2. Winter bud is right triangle, reddish-brown, slanting outwards. Accessory buds are bigger but few. Leaf cordate, flatly spreading, dark green in colour. Tender leaves of this variety are red in colour. The tree looks like fire from afar. So it is called Huo Sang, the Fire-like mulberry, in Chinese. Leaf tip is long caudate. Leaf margin is acute dentate. Leaf base emarginated. Leaf length is 21.8 cm, width 21.3 cm. Leaf blade is thick. Leaf surface smooth with some ripple. Leaf lustre is good. Petiole is medium long and sturdy. Flowering type is monoecious, bearing only staminate or pistillate flowers in a separate cluster. Staminate flowers are rare.

Climatic requirement. Bud sprouting in Hangzhou is from 22 to 25 March. Leaf-opening stage is from 1 to 13 April. Bud sprouting ratio is 70 percent and the bud-growing ratio is 6 percent. Leaves mature from 16 to 26 April, belonging to the early sprouting and early mature variety. Autumn leaves harden in early and middle September.

Average yield per ha. This variety has strong shooting ability. From 1 m shoot, 131 g spring leaves or 138 g autumn leaves can be produced. There are 231 leaves/kg in spring and 139/kg in autumn. Leaves are 46.85 percent of the total weight of twigs, shoots, leaves and fruit. Annual leaf yield is 34 050 kg/ha.

Fruiting habits. Purplish-black soroses are found occasionally. The seeds do not germinate.

Leaf chemical composition. The leaf quality is medium. Leaf DM contains 21.82-23.68 percent of CP and 15.18-16.28 percent of SC.

Main diseases/pests and tolerance. This variety has resistance to Brown spot disease, but it is sensitive to Dwarf diseases, bacterial diseases, Powdery mildew disease and Dirty leaf disease (a fungal disease caused by *Clasterosporium mori* Sydow). It has medium cold resistance. Its tolerance to pruning is low, so it is recommended training as a tree type and planting in odd pieces of land, such as riversides, pondsides and around

houses.

Nong Sang 8

Selected from Zhejiang Province, belonging to the species of White mulberry (*M. alba* L.). It is a diploid, with chromosome number 2n = 2x = 28.

Morphology. The tree is straight. Twigs are medium sturdy and long, somewhat curved, greenish-grey in colour. Internodal distance is 3.4 cm. Leaf order is 2/5 or 3/8. Lenticels are small, round or elliptical, 10/cm^2. Winter bud is right triangle, slanting outwards. Accessory buds are bigger and more. Leaf long cordate, dark green. Leaf tip is caudate. Leaf margin is papillately dentate. Leaf base retuse. Leaf length is 21.5 cm, width 19.9 cm. Leaf blade is comparatively thick. Leaf surface smooth and spreading. Petiole is comparatively long and sturdy. Flowering type is monoecious, bearing only staminate or pistillate flowers in a separate cluster.

Climatic requirement. Bud sprouting in Hangzhou is from 17 to 22 March. Leaf-opening stage is from 20 March to 11 April. Bud sprouting ratio is 88.4 percent and the bud-growing ratio is 14.0 percent. Leaves mature from 16 April to 21 April, belonging to the early sprouting and early mature variety. Autumn leaves harden from middle to late October.

Average yield per ha. This variety has strong shooting ability and few side twigs. From 1 m shoot, 130 g spring leaves or 163.5 g autumn leaves can be produced. There are 444 leaves/kg in spring and 250/kg in autumn. Leaves are 49.68 percent of the total weight of twigs, shoots, leaves and fruits. Annual leaf yield is 45 000 kg/ha.

Fruiting habits. Soroses are abundant, medium-large size, purplish-red.

Leaf chemical composition. The leaf quality is good. Leaf DM contains 23.45-26.13 percent of CP and 14.13-18.28 percent of SC.

Main diseases/pests and tolerance. This variety has resistance to Shrinking-type Mulberry dwarf, Brown spot disease, bacterial diseases, and Dirty leaf disease (caused by *Clasterosporium mori* Sydow). It has broad adaptability to various climatic and soil conditions. It can be propagated by cuttings and trained into a low or medium type.

Yu 2

Selected from the hybridization of "Hu-sang 39 ~Guangdong Jing-sang", belonging to the species of White mulberry (*M. alba* L.). It is a diploid, with chromosome number 2n = 2x = 28.

Morphology. Canopy is somewhat spreading. Twigs are medium sturdy, long and straight, greenish-grey in colour. Internodes are straight. Internodal distance is 4.6 cm. Leaf order is 2/5. Lenticels are large, round or elliptical, 8/cm^2. Winter bud is triangular or nearly round, slanting outwards. Accessory buds are larger and more abundant. Leaf cordate, flatly spreading, light green in colour. Leaf tip is sharp. Leaf margin is obtuse dentate. Leaf

base retuse or linear. Leaf length is 18.8 cm, width 15.9 cm. Leaf blade is comparatively thin. Leaf surface smooth with good lustre. Leaves flatly spread or hang slightly downwards. Petiole is comparatively long and slim. Flowering type is monoecious. Inflorescences of staminate flowers are more and comparatively long.

Climatic requirement. Bud sprouting in Jiangsu is from 30 March to 8 April. Leaf-opening stage is from 10 to 20 April. Bud sprouting ratio is 78 percent and the bud-growing ratio is 20 percent. Leaves mature from 10 to 15 May, belonging to the early sprouting and mid-mature variety. Autumn leaves harden in early September.

Average yield per ha. This variety has strong shooting ability and the side twigs are less. From 1 m shoot, 130 g spring leaves or 84 g autumn leaves can be produced. There are 692 leaves/kg in spring and 278/kg in autumn. Leaves are 42 percent of the total weight of twigs, shoots, leaves and fruit. Annual leaf yield is 31 200 kg/ha.

Fruiting habits. Soroses are few, medium-large size, purplish-black.

Leaf chemical composition. The leaf quality is medium. Leaf DM contains 22.8-26.2 percent of CP and 12.7-14.5 percent of SC.

Main diseases/pests and tolerance. This variety has strong resistance to Yellow-type mulberry dwarf and resistance to Black wilt bacterial disease. However, it is easily attacked by insect pests. It has good tolerance to pruning but weak resistance to drought and cold.

Fertilization recommendations: Higher production of leaf can be achieved by sufficient fertilization. The recommended training is low or medium trunk. Higher density planting is suitable for shoot harvesting.

Zhong Sang 5801

Selected from the hybridization of "Hu-sang 38 ~ Guangdong

Jing-sang", belonging to the species of Guangdong mulberry (*M. atropurpurea* Roxb.). It is a diploid, with chromosome number 2n = 2x = 28.

Morphology. Canopy is somewhat spreading. Twigs are sturdy, long and straight, greenish-grey. Internodes are straight. Internodal distance is 3.7 cm. Leaf order is 2/5. Six lenticels/cm^2. Winter bud is long triangular, earth-yellow in colour, slanting outward. Accessory buds are smaller and few. Leaf long cordate or ovate, flatly spreading, light green in colour. Leaf tip is short caudate. Leaf margin is obtuse dentate. Leaf base retuse or linear. Leaf length is 17.7 cm, width 14.5 cm. Leaf blade is comparatively thick. Leaf surface smooth with lustre. Leaves flatly spread. Petiole is long and sturdy. Flowering type is pistillate.

Climatic requirement. Bud sprouting in Jiangsu starts from early April. Leaf-opening stage is from 13 to 21 April. Bud sprouting ratio is 84 percent and the bud-growing ratio is 15 percent. Leaves mature from 3 to 9 May, belonging to the medium sprouting and mid-mature variety. Autumn leaves harden in the

middle of September.

Average yield per ha. This variety has strong shooting ability and few side twigs. From 1 m shoot, 134 g spring leaves or 96 g autumn leaves can be produced. There are 734 leaves/kg in spring and 266/kg in autumn. Leaves are 41 percent of the total weight of twigs, shoots, leaves and fruit. Annual leaf yield is 23 400 kg/ha.

Fruiting habits. Soroses are abundant, medium-large size, purplish-black.

Leaf chemical composition. The leaf quality is medium. Leaf DM contains 22.3-23.6 percent of CP and 11.3-13.3 percent of SC.

Main diseases/pests and tolerance: This variety has resistance to Yellow-type mulberry dwarf and Black wilt bacterial disease. But it is sensitive to Mulberry powdery mildew and the sorosis disease caused by *Ciboria carunculoids* Whetz. It has good resistance to high moisture but weak tolerance to cold. The

recommended training is low or medium trunk.

Hei You Sang

Indigenous to Sichuan, China. Natural triploid (2n=3x=42), belonging to the species of White mulberry (*M. alba* L.). Mainly cultivated in south Sichuan.

Morphology. The tree is straight. Twigs are medium sturdy and long, dark brown in colour. Internodes are straight. Internodal distance is 4 cm. Leaf order is 2/5. Lenticels are elliptical, 5/cm^2. Winter bud is long triangular, brown, adhering to the branch, slightly tilting to one side. Accessory buds are few. Leaf ovate, flatly spreading, dark green in colour. Leaf tip is sharp. Leaf margin is acute dentate. Leaf base retuse or linear. Leaf length is 22 cm, width 16.5 cm. Leaf blade is comparatively thick. Leaf surface smooth with good lustre. Leaf veins are thick. Leaves hang downwards. Petiole is long and slim. Flowering type is monoecious. Pistillate flowers are more than the staminates. Most of the flowers will drop in the early stage.

Climatic requirement. Bud sprouting in Sichuan is from 17 to 22 March. Leaf-opening stage is from 28 March to 9 April. Bud sprouting ratio is 86 percent and the bud-growing ratio is 25 percent. Leaves mature from 20 to 30 April, belonging to the medium sprouting and mid-mature variety. Autumn leaves harden in early October.

Average yield per ha. This variety has medium shooting ability and the side twigs are few. From 1 m shoot, 251 g spring leaves or 137 g autumn leaves can be produced. There are 362 leaves/kg in spring and 175/kg in autumn. Leaves are 48 percent of the total weight of twigs, shoots, leaves and fruit. Annual leaf yield is 20 700 kg/ha.

Fruiting habits. Soroses are few and small, purplish-black.

Leaf chemical composition. The leaf quality is good. Leaf DM contains 22.54-30.98 percent of CP and 11.23-16.88 percent of SC.

Main diseases/pests and tolerance. This variety has medium resistance to Yellow-type mulberry dwarf, Black wilt bacterial disease, Mulberry powdery mildew and also has resistance to Dirty leaf disease and Brown spot disease caused by fungi.

Fertilization recommendations. This variety can be propagated by cutting, layering or bud-grafting. The recommended training is low or medium trunk.

Da Hua Sang

Indigenous to Sichuan. Natural triploid (2n=3x=42), belonging to the species of White mulberry (*M. alba* L.). Mainly cultivated in south Sichuan.

Morphology. Canopy spreading. Twigs are sturdy and long, Reddish-brown in colour. Internodes are straight. Internodal distance is 4.5 cm. Leaf order is 2/5. Lenticels elliptical, 10/cm^2. Winter bud is circular cone, slanting outwards. Accessory buds are few. Leaf cordate, spreading, light green in colour. Leaf tip is

sharp. Leaf margin is obtuse dentate. Leaf base retuse. Leaf length is 27.5 cm, width 23.5 cm. Leaf blade is thick. Leaf surface smooth with good lustre. Leaves hang slightly downwards. Petiole is long and sturdy. Bearing only staminate flowers. The inflorescences are more.

Climatic requirement. Bud sprouting in Sichuan is from 16 to 26 March. Leaf-opening stage is from 1 to 8 April. Bud sprouting ratio is 70.4 percent and the bud-growing ratio is 22 percent. Leaves mature in mid-May, belonging to the medium sprouting and late-mature variety. Autumn leaves harden in early October.

Average yield per ha. This variety has medium shooting ability and the side twigs are few. From 1 m shoot, 168 g spring leaves or 163 g autumn leaves can be produced. There are 408 leaves/kg in spring and 202/kg in autumn. Leaf weight occupies 46.21 percent of the total weight of twigs, shoots, leaves and fruit. Annual leaf yield is 18 000 kg/ha.

Leaf chemical composition. The leaf quality is good. Leaf DM

contains 27.7-29.4 percent of CP and 11.25-12.63 percent of SC.

Main diseases/pests and tolerance. This variety has medium resistance to Yellow-type mulberry dwarf, Mulberry powdery mildew and Brown spot disease, but is lightly sensitive to Black wilt bacterial disease. The tolerance to drought and cold is comparatively weak.

Fertilization recommendations. This variety is suitable for planting in good soil conditions so as to achieve high productivity. The recommended training is medium or high trunk.

Xiao Guan Sang

Native variety of Sichuan, China. Diploid (2n=2x=28), belonging to the species of White mulberry (*M. alba* L.). Widely distributed in the east and north of Sichuan.

Morphology. The tree is straight. Twigs are slim and long, greenish-grey in colour. Internodes are straight. Internodal

distance is 3 cm. Leaf order is 2/5. Lenticels are mostly small and round, 15/cm^2. Winter bud is right triangular, light greenish-brown in colour, adhering to the branch. Accessory buds are few and smaller. Leaf ovate, flatly spreading, dark green in colour. Few incised leaves appear in the basic part of the shoot. Leaf tip is sharp. Leaf margin is papillate dentate. Leaf base emarginate. Leaf length is 18.5 cm, width 14.5 cm. Leaf blade is thick. Leaf surface smooth and slightly shrivelled, good lustre. Leaves are flatly spreading. Petiole is short and slim. Flowering type is monoecious, with short style. Inflorescences of staminate flowers are few.

Climatic requirement. Bud sprouting in Sichuan is from 12 to 15 March. Leaf-opening stage is from 17 March to 20 April. Bud sprouting ratio is 80 percent and the bud-growing ratio is 27 percent. Leaves mature in early May, belonging to the early sprouting and early mature variety. Autumn leaves harden in early October.

Average yield per ha. This variety has few side twigs. From 1 m

shoot, 226 g spring leaves or 92 g autumn leaves can be produced. There are 456 leaves/kg in spring and 225/kg in autumn. Leaves are 66.7 percent of the total weight of twigs, shoots, leaves and fruit. Annual leaf yield is 18 750 kg/ha.

Fruiting habits. Soroses are few and small, purplish-black.

Leaf chemical composition. The leaf quality is medium. Leaf DM contains 18.83-21.97 percent of CP and 14.5 percent of SC.

Main diseases/pests and tolerance. This variety has medium resistance to Dirty leaf disease and Mulberry powdery mildew, but is sensitive to Yellow-type mulberry dwarf and Black wilt bacterial disease. It also easily contracts Brown spot disease. It has strong tolerance to drought and medium tolerance to cold.

Fertilization recommendations. This variety has broad adaptability to various soil and climatic conditions. It is suitable for planting in the scattered land of hilly areas, and trained into low or medium trunk.

Jia Ling 16

A triploid bred by crossing "Xiqing" (tetraploid) with "Yu 2" (diploid). Since 1992, it has been widely cultivated in all of Sichuan and introduced to other provinces, such as Xinjiang, Guizhou, Henan and Shaanxi.

Morphology. Twigs are sturdy, straight and long, greenish-grey. Winter bud is triangular, closely adhering to the branch. Leaf order is 2/5. Internodal distance is 3.6 cm. Leaf incised, large in size, dark green in colour. Leaf tip is short and sharp. Leaf margin is acute dentate. Leaf base emarginate. Leaf length is 28 cm, width 25.5 cm. Leaf blade is thick. Leaf surface smoothly shrivelled. Petiole is short and sturdy. Bearing very few pistillate flowers, it is sterile.

Climatic requirement. Bud sprouting in Sichuan is in the middle of March, belonging to early-sprouting and mid-mature variety. Bud sprouting ratio is above 80 percent.

Average yield per ha. This variety has high productivity.

Fruiting habits. Sterile.

Leaf chemical composition. Good leaf quality. Leaf DM contains 28.05 percent of CP in average of spring and autumn.

Main diseases/pests and tolerance: This variety has relatively strong resistance to Black wilt bacterial disease. Leaf quality can be maintained for a long time in storage.

Planting recommendations. Good fertilization and management for this variety can lead to high productivity. It is suitable for hilly and mountainous areas with high density or intercropping.

Guangdong Jing Sang

A highly heterogeneous variety originating from the Pearl River Delta of Guangdong, widely distributed in south China. Diploid (2n=2x=28), belonging to the species of Guangdong mulberry (*M.*

atropurpurea Roxb.).

Morphology. Straight tree. Twigs are slim, straight and long. Bark colour is not uniform, mostly greenish-grey or brown. Internodes are straight or slightly curved. Internodal distance is 3.4 cm. Leaf order is mostly 2/5. Lenticels are round or elliptical, 8/cm^2. Winter bud is large, triangular or nearly globular, mostly slanting outwards. Ovate or cordate leaf, entire, occasionally incised or mixed. Leaf flatly spread, light green. Leaf tip is sharp or short caudate. Leaf margin is obtuse or acute dentate. Leaf base retuse or linear, not symmetrical. Leaf length is 17 cm, width 14 cm. Thin leaf blade. Smooth leaf surface not shrivelled, weak lustre. Leaves are flatly spread. Petiole is slim, medium length. Flowering type is monoecious or dioecious, occasionally both staminate and pistallate flowers are found in a separate cluster. Inflorescences of staminate flowers are abundant and long.

Climatic requirement. Bud sprouting in Guangzhou is from 18 to 21 January. Leaf-opening stage is from 2 to 21 February. Bud sprouting ratio is 85 percent and the bud-growing ratio is 20

percent. First crop leaves mature from 27 February to 17 March. Growing period is 25-30 days for whole leaf and 40-45 days for the leaf-shoot respectively, belonging to the early sprouting and early mature type.

Average yield per ha. This variety has very strong shooting ability, with many side twigs, and uniform growth. From 1 m shoot, 85 g spring leaves or 65 g autumn leaves can be produced. There are 441 leaves/kg in the main branch and 945/kg in side twigs. Annual leaf yield can reach 33 750 kg/ha.

Fruiting habits. Soroses are abundant and large, purplish-black.

Leaf chemical composition. Medium leaf quality. Leaf DM contains 21.24 percent of CP and 8.38 percent of SC.

Main diseases/pests and tolerance. This variety has resistance to Common mulberry dwarf but is sensitive to Dirty leaf disease, Mulberry powdery mildew and Green bacterial wilt (caused by *Pseudomonas solanacearum* Smith. It has strong tolerance to

pruning and moisture condition, but weak resistance to drought and cold.

Planting recommendations. This variety can be propagated by seedlings and planted in at very high density (90 000-120 000 plants/ha). High yielding can be achieved by providing sufficient fertilization after each harvest.

Lun 40

A high yielding variety selected from Guangdong Jing Sang. Natural triploid (2n=3x=42), belonging to the species of Guangdong mulberry (*M. atropurpurea* Roxb.), widely distributed in south China.

Morphology. Canopy slightly spread. Twigs are sturdy, straight and long, brown. Internodes are straight. Internodal distance is 3.8 cm. Leaf order is 2/5 or 3/8. Lenticels are round or elliptical, 5/cm^2. Winter bud is large, oval shape, brown, slanting outwards. Accessory buds are many and large. Cordate leaf, flatly spread,

light green. Tender leaves look purplish-red. Leaf tip is short caudate. Leaf margin is papillately dentate. Retuse leaf base. Leaf length is 24.5 cm, width 16.95 cm. Leaf blade is relatively thick. Smooth leaf surface not shrivelled, good lustre. Leaves hang slightly downwards. Petiole is sturdy and long. Flowering type is pistallate.

Climatic requirement. Bud sprouting in Guangzhou is from 16 to 28 January. Leaf-opening stage is from 2 to 15 February. Bud sprouting ratio is 80 percent and the bud-growing ratio is 17 percent. First crop leaves mature from 18 February to 10 March. Growing period is 25-30 days for whole leaf and 40-45 days for the leaf-shoot respectively, belonging to the early sprouting and early mature type.

Average yield per ha. This variety has medium shooting ability, with few side twigs. From 1 m shoot, 175 g spring leaves or 120 g autumn leaves can be produced. There are 178 leaves/kg in the main branch and 475/kg inside twigs. Annual leaf yield can reach 46 500 kg/ha.

Fruiting habits. Soroses are abundant and large, purplish-black, but seed fertility is very low.

Leaf chemical composition. Medium leaf quality. Leaf DM contains 21.06-25.01 percent of CP and 7-7.9 percent of SC.

Main diseases/pests and tolerance. This variety grows very fast and with strong tolerance to pruning. It is lightly sensitive to Dirty leaf disease, Green bacterial wilt caused by *Pseudomonas solanacearum* Smith and Red rust disease caused by *Accidium mori* (Board) Diet. Its resistance to drought and cold is also weak.

Planting recommendations. This variety can be planted at high density (90 000 plants/ha). Additional applications of phosphorus and potassium are needed for new plantations.

Lun 109

Selected from Pearl River Delta of Guangdong. Diploid

(2n=2x=28), belonging to the species of Guangdong mulberry (*M. atropurpurea* Roxb.).

Morphology. Canopy slightly spread. Twigs are sturdy, straight and long, greyish-brown. Internodes are slightly curved. Internodal distance is 3.8 cm. Leaf order is 3/8. Lenticels are round or elliptical, 9/cm^2. Winter bud is oval shape, light brown, slanting outwards. Accessory buds are many and large. Ovate or cordate leaf, light green. Short caudate leaf tip. Leaf margin is papillately dentate, slightly bending upwards. Retuse leaf base. Leaf length is 27 cm, width 20.2 cm. Leaf blade is relatively thick. Petiole is sturdy and long. Flowering type is staminate, with long inflorescence. Pistallates are rarely found.

Climatic requirement. Bud sprouting in Guangzhou is from 16 to 31 January. Leaf-opening stage is from 5 to 21 February. Bud sprouting ratio is 68 percent and the bud-growing ratio is 27 percent. First crop leaves mature from 24 February to 10 March. Growing period is 25-30 days for whole leaf and 40-45 days for the leaf-shoot respectively, belonging to the early sprouting and

mid-mature type.

Average yield per ha. This variety has strong shooting ability. It grows fast, with early sprouting and sturdy side twigs. From 1 m shoot, 147 g spring leaves or 110 g autumn leaves can be produced. There are 192 leaves/kg in the main branch and 583/kg in side twigs. Annual leaf yield can reach 39 450 kg/ha.

Leaf chemical composition. Medium leaf quality. Leaf DM contains 29.47 percent of CP and 7.61 percent of SC.

Main diseases/pests and tolerance. This variety has medium tolerance to drought but weak tolerance to cold. It is sensitive to Green bacterial wilt caused by *Pseudomonas solanacearum* Smith.

Planting recommendations: This variety can be planted at high density (90 000 plants/ha). Apply nitrogen fertilizer after each harvest and additional phosphorous and potassium after the second harvest.

Sha 2

Selected from Pearl River Delta of Guangdong. Diploid (2n=2x=28), belonging to the species of Guangdong mulberry (*M. atropurpurea* Roxb.).

Morphology: Canopy slightly spread. Twigs are sturdy, straight and long, yellowish-brown. Straight internodes. Internodal distance is 5.2 cm. Leaf order is 2/5.5 lenticels/cm^2. Winter bud is triangular, greyish-brown, adhering to the branch. Many and large accessory buds. Ovate or long cordate leaf, flatly spread, green. Tender leaves look light purplish-red. Leaf tip is short caudate. Leaf margin is papillately dentate. Linear leaf base. Leaf length is 30.7 cm, width 21.5 cm. Leaf blade is relatively thick. Petiole is sturdy and short. Flowering type is pistillate, with short style.

Climatic requirement. Bud sprouting in Guangzhou is from 20 to 31 January. Leaf-opening stage is from 3 to 23 February. Bud sprouting ratio is 62.9 percent and the bud-growing ratio is 37.1

percent. First crop leaves mature from 20 February to 10 March. Growing period is 25-30 days for whole leaf and 40-45 days for the leaf-shoot respectively, belonging to the early sprouting and early mature type.

Average yield per ha. This variety has medium shooting ability, with early sprouting and many side-twigs. From 1 m shoot, 109 g spring leaves or 81 g autumn leaves can be produced. There are 154 leaves/kg in the main branch and 294/kg in side twigs. Annual leaf yield can reach 39 000 kg/ha.

Fruiting habits. Soroses are abundant and large, purplish-black.

Leaf chemical composition. Medium leaf quality. Leaf DM contains 22.88 percent of CP and 10.88 percent of SC.

Main diseases/pests and tolerance. This variety has strong resistance to mulberry thrips (*Pseudodendrothrips mori* Niwa) and mulberry leaf mite (*Tetranychus cinnabarinus* Boisoluval and *Eotetranychus suginanamensis* Yokoyama). However, it is

sensitive to Green bacterial wilt caused by *Pseudomonas solanacearum* Smith. It has tolerance to moisture and medium tolerance to drought, but its tolerance to cold is weak.

Planting recommendations: For seed production purposes, more phosphorus and potassium are needed in fertilizer. When soroses appear red, apply nitrogen fertilizer slightly to promote fruiting.

Da 10

A natural triploid (2n=3x=42) Selected from Pearl River Delta of Guangdong, belonging to the species of Guangdong mulberry (*M. atropurpurea* Roxb.).

Morphology. Canopy slightly spread. Twigs are slim, straight and long, light brown. Internodes are straight. Internodal distance is 4.8 cm. Leaf order is 1/2. Lenticels are round or elliptical, 6/cm^2. Winter bud is triangular, brown, slanting outwards. Accessory buds are many and large. Cordate leaf, spread, light green. Long caudate leaf tip. Acute dentate leaf margin. Emarginate leaf base.

Leaf length is 22 cm, width 18.3 cm. Smooth leaf surface and slightly shrivelled, with weak lustre. Leaves hang slightly downwards. Petiole is sturdy and short. Flowering type is pistillate, without style.

Climatic requirement. Bud sprouting in Guangzhou is from 16 to 28 January. Leaf-opening stage is from 31 to 16 February. Bud sprouting ratio is 85 percent and the bud-growing ratio is 10 percent. First crop leaves mature from 20 February to 10 March. Growing period is 25-30 days for whole leaf and 40-45 days for the leaf-shoot respectively, belonging to the early sprouting and early mature type.

Average yield per ha: This variety has medium shooting ability, with few side twigs. Annual leaf yield is 30 000 kg/ha. Fruit production can reach 15 000 kg/ha per year.

Fruiting habits. Soroses are abundant and large, purplish-black. The fruit contains 2.78-3.8 percent of total carbohydrate, 2.28-3.57 percent of reducing sugar, 0.81 percent of amino acids.

Vitamin C content of the berry reaches 1.02 mg/100 g, adequate for processing and beverage production.

Main diseases/pests and tolerance: This variety is slightly sensitive to Mulberry mosaic disease caused by virus. It is also easily attacked by insect pests. Its tolerance to cold is weak.

Planting recommendations: For fruit production purposes, more fertilizer, with phosphorous and potassium, is needed. Two prunings are possible, in April and in July/August. Nitrogen fertilizer should be applied between prunings.

Kang Qing 10

A resistant variety selected from the west of Guangdong. Diploid (2n=2x=28), belonging to the species of Guangdong mulberry (*M. atropurpurea* Roxb.).

Morphology: Canopy slightly spread. Twigs are sturdy, straight and long, greyish-brown. The sun-facing side of the tender shoot

is light reddish-brown and the top bud is curved. Internodes are straight. Internodal distance is 4.9 cm. Leaf order is 1/2. Lenticels are round, 9/cm^2. Winter bud is triangular, greyish brown, slanting outwards. Accessory buds are few and smaller. Cordate leaf, occasionally incised, spread, light green. Sharp leaf tip. Obtuse dentate leaf margin. Linear leaf base. Leaf length is 27.3 cm, width 24.4 cm. Thick leaf blade. Smooth leaf surface with good lustre. Leaves hang slightly downwards. Petiole is sturdy and short. Flowering type is staminate, with many long inflorescences. Monoecism is found occasionally.

Climatic requirement. Bud sprouting in Guangzhou is from 26 January to 5 February. Leaf-opening stage is from 11 to 24 February. Bud sprouting ratio is 80 percent and the bud-growing ratio is 15 percent. First crop leaves mature from 16 February to 5 March. Growing period is 20-25 days for whole leaf and 35-40 days for the leaf-shoot respectively, belonging to the early sprouting and early mature type.

Average yield per ha. This variety has strong shooting ability,

grows fast, with many side twigs. From 1 m shoot, 130 g spring leaves or 100 g autumn leaves can be produced. There are 206 leaves/kg in the main branch and 311/kg in the side twigs. Annual leaf yield can reach 37 050 kg/ha.

Leaf chemical composition. Medium leaf quality. Leaf DM contains 22.4 percent of CP and 5.26 percent of SC.

Main diseases/pests and tolerance. This variety has strong resistance to Mulberry green bacterial wilt and Mulberry powdery mildew, medium resistance to Mulberry red rust disease. However, it is easily attacked by mulberry thrips and mulberry leaf mite. It has weak tolerance to cold. It has strong rooting ability and can be propagated by cuttings.

Hei Lu Cai Sang

Indigenous to Shandong China, belonging to the species of Lu mulberry (*M. multicaulis* P.). Chromosome number is 2n = 2x = 28.

Morphology. Straight tree. Twigs are slim and straight, medium long. Greenish-brown bark. Internodes are slightly curved. Internodal distance is 3 cm. Leaf order is 2/5. Lenticels are elliptical, 7/cm^2. Winter bud is triangle, dark brown, adhering to the branch. Accessory buds are smaller and less. Ovate leaf, margin slightly bends upwards. Leaf colour dark green. Caudate leaf tip. Papillately dentate leaf margin. Leaf base retuse or linear. Leaf length is 18 cm, width 14 cm. Leaf blade is comparatively thick. Smooth leaf surface slightly shrivelled, with good lustre. Leaves flatly spread. Petiole is long and slim. Monoecious flowering type. Inflorescences of staminate flowers are short but abundant.

Climatic requirement. Bud sprouting in Shandong is from 22 to 25 April. Leaf-opening stage is from 28 April to 8 May. Bud sprouting ratio is 75 percent and bud-growing ratio is 15 percent. Leaves mature on 14 May, belonging to the medium sprouting and mid-mature type. Autumn leaves harden in early September.

Average yield per ha. This variety has strong shooting ability with

many side branches. From 1 m shoot 98 g leaves can be produced in spring and 116 g in autumn. There are 670 leaves/kg in spring and 275/kg in autumn. Leaves are 49.3 percent of the total weight of twigs, shoots, leaves and fruits. Annual leaf yield is 19 500 kg/ha.

Fruiting habits. Soroses are few and small, purplish-black.

Leaf chemical composition. Good leaf quality. Leaf DM contains 23.8-24.1 percent of CP and 13.2-18.3 percent of SC.

Main diseases/pests and tolerance. This variety has medium resistance to Brown spot disease. It has strong cold resistance and good tolerance to wind. *Planting recommendations*: Recommended for Yellow River area and to be trained into low or medium trunk.

Da Ji Guan Sang

Indigenous to Shandong, belonging to the species of Lu mulberry

(*M. multicaulis* Perr.) Chromosome number is 2n = 2x = 28.

Morphology: Canopy is slightly spread. Twigs are sturdy, short and straight. Brown bark. Straight internodes. Internodal distance is 3 cm. Leaves have no order. Lenticels are small and round, 5/cm^2. The top of the shoot swells like a cock's comb, so it is called Da Ji Guan (Big cock's comb) in Chinese. Brownish-red winter buds. The buds in the middle and lower parts of the shoot are triangular or nearly globular, some of them are slanting outwards. Few and small accessory buds. Ovate leaf, spread or leaf margin slightly bent upwards. Dark green leaves. Sharp leaf tip. Papillately dentate leaf margin. Retuse leaf base. Leaf length is 24 cm, width 20 cm. Thick leaf blade. Smooth leaf surface not shrivelled, with good lustre. Leaves hang slightly downwards. Petiole is sturdy and short. Monoecious flowering type. Inflorescences of staminate flowers are short but abundant.

Climatic requirement. Bud sprouting in Shandong is from 22 to 26 April. Leaf-opening stage is from 29 April to 7 May. Bud sprouting ratio is 85 percent and bud-growing ratio is 25 percent. Leaves

mature on 16 May, belonging to the medium sprouting and mid-mature variety. Autumn leaves harden in mid-August.

Average yield per ha. This variety has medium shooting ability with many side branches. From 1 m shoot 212 g leaves can be produced in spring and 184 g in autumn. There are 660 leaves/kg in spring and 240/kg in autumn. Leaves are 59.3 percent of the total weight of twigs, shoots, leaves and fruit. Annual leaf yield is 20 000 kg/ha.

Fruiting habits. Soroses are few and small, purplish-black.

Leaf chemical composition. Good leaf quality. Leaf DM contains 23.1-27.2 percent of CP and 12-17.1 percent of SC.

Main diseases/pests and tolerance. This variety has strong resistance to cold and wind. It has low tolerance to pruning. It is sensitive to Black wilt bacterial disease, Mulberry red rust and Brown spot disease.

Planting recommendations. Recommended for Yellow River area and to be trained into medium or high trunk.

Xuan 792

Selected from the variants of native mulberry in Shandong, belonging to the species of Lu mulberry (*M. multicaulis* Perr.). Chromosome number is 2n = 2x = 28. Widely distributed in Shandong and provinces in North China.

Morphology. Canopy is slightly spread. Twigs are sturdy, long and straight. Brown bark. Internodes are slightly curved. Internodal distance is 3.5 cm. Leaf order is 2/5. Lenticels are round, 5/cm^2. Winter bud is triangular, adhering to the branch. Accessory buds are small and few. Ovate leaf, spread, dark green. Leaf tip is sharp or short caudate. Obtuse dentate leaf margin. Linear leaf base. Leaf length is 23 cm, width 17 cm. Thick leaf blade. Smooth leaf surface and not shrivelled, with good lustre. Leaves hang slightly downwards. Petiole is medium sturdy and long. Pistillate flowering type.

Climatic requirement. Bud sprouting in Shandong is from 24 to 28 April. Leaf-opening stage is from 1 to 10 May. Bud sprouting ratio is 73 percent and the bud-growing ratio is 15 percent. Leaves mature on 16 May, belonging to the late sprouting and mid-mature variety. Autumn leaves harden in early September.

Average yield per ha: This variety has strong shooting ability with few side branches. From 1 m shoot 112 g leaves can be produced in spring and 138 g in autumn. There are 410 leaves/kg in spring and 190/kg in autumn. Leaves are 49.79 percent of the total weight of twigs, shoots, leaves and fruits. Annual leaf yield is 30 000 kg/ha.

Fruiting habits. Soroses are few, medium size, purplish-black.

Leaf chemical composition. Good leaf quality. Leaf DM contains 25.2-27.5 percent of CP and 11.3-15.3 percent of SC.

Main diseases/pests and tolerance. This variety has medium resistance to Yellow-type mulberry dwarf, strong tolerance to

wind, cold and drought. It is lightly sensitive to Shrinking-type mulberry dwarf.

Planting recommendation. This variety is suitable to plant in the north of China and to train into low or medium trunk. Higher planting density and application of fertilizer in autumn can lead to higher production.

Niu Gen Sang

Native variety of Hebei China, belonging to the species of Lu mulberry (*M. multicaulis* Perr.). Chromosome number is 2n = 2x = 28. Widely distributed in Hebei Province.

Morphology. Canopy is slightly spread. Twigs are sturdy and long, slightly curved. Greyish brown bark. Internodes are slightly curved. Internodal distance is 4.5 cm. Leaf order is 2/5. Lenticels are comparatively small, round or elliptical, 9/cm^2. Winter bud is right triangular, light yellowish-brown in colour, slanting outwards. Accessory buds are small and few. Cordate leaf, spread, dark

green. Sharp leaf tip. Papillately dentate leaf margin. Retuse leaf base. Leaf length is 23.5 cm, width 19.5 cm. Leaf blade is thick. Smooth leaf surface, slightly shrivelled. Leaf margin is bent slightly upwards. Sturdy leaf vein. Petiole is sturdy and long. Flowering type is monoecious. Inflorescences of staminate flowers are few and short.

Climatic requirement. Bud sprouting in Hebei is from 6 to 12 May. Leaf-opening stage is from 14 to 20 May. Bud sprouting ratio is 72 percent and the bud-growing ratio is 20 percent. Leaves mature from 25 May to 1 June, belonging to the medium sprouting and mid-mature type. Autumn leaves harden from 10 to 15 September.

Average yield per ha. This variety has medium shooting ability, with few side branches. From 1 m shoot 155 g leaves can be produced in spring and 140 g in autumn. There are 400 leaves/kg in spring and 160/kg in autumn. Leaves are 50 percent of the total weight of twigs, shoots, leaves and fruit. Annual leaf yield is 15 000 kg/ha.

Fruiting habits. Soroses are few, medium size, purplish-black.

Leaf chemical composition. Medium leaf quality. Leaf DM contains 16.25 percent of CP and 13.41 percent of SC.

Main diseases/pests and tolerance. This variety has resistance to Mulberry anthracnose disease caused by *Colletotrichum morifolium* Hora and the Mulberry leaf blight caused by *Hormodendrum mori* Yendo. It is sensitive to Black wilt bacterial disease and Dirty leaf disease. Its tolerance to cold and drought is medium.

Planting recommendation. This variety is suitable for planting in the north of China and for training into medium trunk, high trunk or tree type. Properly high planting density is recommended.

Hong Pi Wa Sang

Native variety of Hubei China, belonging to the species of Lu mulberry (*M. multicaulis* P.). Chromosome number is 2n = 2x =

28.

Morphology. Canopy is spread. Twigs are sturdy, long and straight. Brown bark. Internodes are straight. Internodal distance is 4 cm. Leaf order is 2/5. Lenticels are round or elliptical, 8/cm^2. Winter bud is triangular, brown in colour. Buds are slanting outwards or adhering to the branch. Few accessory buds. Cordate leaf, light green. Sharp leaf tip. Papillately dentate leaf margin. Leaf base retuse or linear. Leaf length is 21 cm, width 19 cm. Thick leaf blade. Leaf surface is smooth and shrivelled, with weak lustre. Leaves hang slightly downwards. Petiole is medium sturdy and long. Pistillate flowering type.

Climatic requirement. Bud sprouting in Zhenjiang is from 13 to 17 April. Leaf-opening stage is from 18 to 23 April. Bud sprouting ratio is 56 percent and bud-growing ratio is 15 percent. Leaves mature from 15 May to 20 May, belonging to the late sprouting and late mature type. Autumn leaves harden in the middle of September.

Average yield per ha. This variety has weak shooting ability, but grows fast with few side branches. From 1 m shoot 119 g leaves can be produced in spring and 120 g in autumn. There are 548 leaves/kg in spring and 165/kg in autumn. Leaves are 54 percent of total weight of twigs, shoots, leaves and fruits. Annual leaf yield is 18 000 kg/ha.

Fruiting habits. Soroses are small and few, purplish-black.

Leaf chemical composition. Medium leaf quality. Leaf DM contains 23.6-26.4 percent of CP and 10.8-11.5 percent of SC.

Main diseases/pests and tolerance. This variety has medium resistance to Black wilt bacterial disease, Mulberry powdery mildew and Dirty leaf disease. It is sensitive to Yellow-type mulberry dwarf.

Planting recommendation. This variety is suitable for planting in the Yangtze River area, trained into medium or high trunk type. Maintaining more shoots or proper higher planting density are

recommended.

Hei Ge Lu

Native variety of Shanxi China, belonging to the species of White mulberry (*M. alba* L.). Chromosome number is 2n = 2x = 28.

Morphology. Canopy is slightly spread. The twigs are medium sturdy, long and straight. Brown bark. Straight internodes. Internodal distance is 3.3 cm. Leaf order is 2/5. Lenticels are round, small and few, 8/cm^2. Winter bud is right triangular, brown, slanting outwards. Accessory buds are few and not obvious. Ovate leaf, spread, dark green. Sharp leaf tip. Obtuse dentate leaf margin. Retuse leaf base. Leaf length is 19.4 cm, width 16.8 cm. Thick leaf blade. Smooth leaf surface, slightly shrivelled, with good lustre. Leaves hang slightly downwards. Petiole is medium sturdy and long. Monoecious flowering type. Inflorescences of staminate flowers are few and short.

Climatic requirement. Bud sprouting in Shanxi is from 18 to 25

April. Leaf-opening stage is from 27 April to 4 May. Bud sprouting ratio is 80 percent and the bud-growing ratio is 27 percent. Leaves mature from 20 to 26 May, belonging to the medium sprouting and medium mature type. Autumn leaves harden in 20 September.

Average yield per ha. This variety has strong shooting ability, with few side branches. From 1 m shoot 125 g of leaves can be produced in spring and 140 g in autumn. There are 428 leaves/kg in spring and 256/kg in autumn. Leaves are 41 percent of total weight of twigs, shoots, leaves and fruit. Annual leaf yield is 20 250 kg/ha.

Fruiting habits. Soroses are small and few, purplish-black.

Leaf chemical composition. Medium leaf quality. Leaf DM contains 23.4 percent of CP and 13.2 percent of SC.

Main diseases/pests and tolerance. This variety has medium resistance to Mulberry powdery mildew. It is lightly sensitive to

Yellow-type mulberry dwarf and sensitive to Black wilt bacterial disease. It has strong tolerance to drought, cold and poor soil conditions.

Planting recommendation. This variety is suitable for planting by road- and riversides, trained into medium or high trunk type.

He Tian Bai Sang

A triploid variety (2n = 3x = 42) selected from south Xinjiang, belonging to the species of White mulberry (*M. alba* L.).

Morphology. Canopy is spread. Twigs are slim and long, some bending. Brown bark colour. Straight internodes. Internodal distance is 5 cm. Leaf order is 2/5. Lenticels are large, mostly elliptical, 5/cm^2. Winter bud is long triangular, brown, adhering to the branch. Some buds are tilting to one side. Accessory buds are larger and more. Cordate leaf. Entire and incised leaves are mixed together. Incised leaf has 1-10, mostly 5, gaps. Leaf is flatly spread, dark green. Short caudate leaf tip. Obtuse dentate

leaf margin. Emarginate leaf base. Leaf length is 12.6 cm, width 11.6 cm. Thick leaf blade. Smooth leaf surface, not shrivelled, with weak lustre. Leaves hang slightly downwards. Petiole is slim and medium long. Pistillate flowering type.

Climatic requirement. Bud sprouting in south Xinjiang is from 13 to 16 April. Leaf-opening stage is from 17 to 22 April. Bud sprouting ratio is 82 percent and bud-growing ratio is 21 percent. Leaves mature from 10 to 15 May, belonging to the medium sprouting and medium mature type. Autumn leaves harden in early September.

Average yield per ha. This variety has strong shooting ability with many side branches. From 1 m shoot 166 g of leaves can be produced in spring and 45 g in autumn. There are 476 leaves/kg in spring and 348/kg in autumn. Leaves are 46.9 percent of total weight of twigs, shoots, leaves and fruit. Annual leaf yield is 17 700 kg/ha.

Fruiting habits. Soroses are abundant, medium size, jade-white

and sweet, (containing 18.9 percent sugar).

Leaf chemical composition. Good leaf quality. Leaf DM contains 22.1-23.3 percent of CP and 11.0-14.2 percent of SC.

Main diseases/pests and tolerance. This variety has strong resistance to drought and cold.

Planting recommendation. The recommended training type is low or medium trunk. Higher production can be achieved by providing good fertilization and irrigation. If for both fruit and leaf production, high trunk or tree type is preferable.

Yun Sang 2

A diploid variety (2n = 2x = 28) selected from Yunnan, belonging to the species of White mulberry (*M. alba* L.).

Morphology. Canopy is slightly spread. Twigs are medium sturdy, straight and long, greyish-green. Internodes are straight. Internodal distance is 4.3 cm. Leaf order is 2/5. Lenticels are

round or elliptical, 7/cm^2. Winter bud is long triangular, reddish-brown, slanting outwards with slightly tilting to one side. Accessory buds are small and few. Long cordate leaf, flatly spread, light green. Leaf tip is short caudate or sharp. Obtuse dentate leaf margin. Leaf base retuse or linear. Leaf length is 19.5 cm, width 15 cm. Thin leaf blade. Smooth leaf surface, shrivelled or not, with weak lustre. Petiole is medium in size and length. Flowering type is pistillate.

Climatic requirement. Bud sprouting in Yunnan is from 1 to 21 February. Leaf-opening stage is from 16 to 21 February. Bud sprouting ratio is 78 percent and bud-growing ratio is 20 percent. Leaves mature from 15 March to 20 March, belonging to the medium sprouting and medium mature type. Autumn leaves harden in early October.

Average yield per ha. This variety has strong shooting ability with few side branches. From 1 m shoot 154 g leaves can be produced in spring and 132 g in autumn. There are 600 leaves/kg in spring and 250/kg in autumn. Leaves are 36 percent of total

weight of twigs, shoots, leaves and fruit. Annual leaf yield is 27 000 kg/ha.

Fruiting habits. Soroses are abundant, medium size, purplish-black.

Leaf chemical composition. Medium leaf quality. Leaf DM contains 21.5 percent of CP and 12 percent of SC.

Planting recommendation. The recommended training type is low or medium trunk.

Dao Zhen Sang

A native variety selected from Guizhou, diploid (2n = 2x = 28), belonging to the species of White mulberry (*M. alba* L.).

Morphology. Canopy is slightly spread. The twigs are medium sturdy, straight and long, greyish-white. Internodes are straight. Internodal distance is 3 cm. Lenticels are round and small,

21/cm^2. Winter bud is triangular, light yellow in colour, slanting outwards. Accessory buds are few. Leaf is cordate, flatly spreading, light green in colour. Leaf tip is short caudate or sharp. Papillately dentate leaf margin. Emarginate leaf base. Leaf length is 18 cm, width 14 cm. Leaf surface smooth and slightly shrivelled, with lustre. Petiole is slim and short. Flowering type is staminate, bearing short and few inflorescences.

Climatic requirement. Bud sprouting in Jiangsu is from 3 to 9 April. Leaf-opening stage is from 12 to 17 April. Bud sprouting ratio is 75 percent and the bud-growing ratio is 28 percent. Leaves mature from 1 to 5 May, belonging to the early sprouting and early mature type. Autumn leaves harden in early September.

Average yield per ha. This variety has strong shooting ability with few side branches. From 1 m shoot 137 g of leaves can be produced in spring and 90 g in autumn. There are 968 leaves/kg in spring and 376/kg in autumn. Leaves are 50 percent of total weight of twigs, shoots, leaves and fruits. Annual leaf yield is 22 500 kg/ha.

Leaf chemical composition. Medium leaf quality. Leaf DM contains 22.01-24.58 percent of CP and 13.8-13.58 percent of SC.

Main diseases/pests and tolerance. This variety has medium resistance to Black wilt bacterial disease and resistance to Yellow-type mulberry dwarf. Its tolerance to cold is poor.

Planting recommendation. This variety is recommended for planting by roadsides and field boundaries, and to be trained into medium or high trunk.

CULTIVATION METHODS

Propagation

Sexual methods (seedling) and asexual methods (grafting, cutting, layering, etc.) are used for mulberry propagation. The good characteristics of the parent plants can be assured by asexual propagation. In order to establish a fast growing and high yielding

mulberry plantation, the propagation of improved F1 hybrids by seedlings is recommended.

In the tropical and subtropical areas, mulberry can grow very fast and be harvested many times. Seedlings of local Jing mulberry are traditionally used in south China. During the 1970s, the technique of breeding and propagating of improved F1 hybrids was developed in Guangdong. In 1977, the good combinations "Sha 2 ~ Lun 109" and "Tang 10 ~ Lun 109" were selected. Their leaf yield increased by 20 percent over the Jing variety. These F1 hybrids spread in south China very rapidly. Later they were taken to some areas in east and north China with success.

The key techniques for propagation of seedling of hybrids are as follows:

Seed harvesting. The seeds are harvested in April. They number 450 000 to 500 000/kg.

Sowing. The land selected as nursery must be fertile,

convenient for irrigation and drainage and without diseases and insect pests. The seeds can be sown by broadcasting. The temperature required for germination is above 13 ºC. The germination rate of seeds is 80-85 percent and survival rate 40-50 percent. By sowing 15kg seeds per ha, 180 000-200 000 seedlings can be produced.

Nursery management. After sowing, the nursery is covered with rice straw and sprinkled with water to retain moisture. When the young seedling sprouts two true leaves about ten days later, part of the covering straw can be removed. Weeding and thinning are required. When the seedling has four or five leaves, 0.3-0.5 percent urea solution should be sprinkled over at intervals of five to seven days. The seedlings can grow up to 30 cm height 90 days after sowing in spring. They can reach 60-100 cm within 120-150 days in the nursery.

Transplanting. Seedlings sown in spring can be transplanted in autumn or winter of the same year, while those sown in autumn can be transplanted in the following spring. If the mulberry is newly planted in January, the first crop of leaves can be harvested in May and the leaf yield of the first year can reach 26 250 kg/ha. If the mulberry is planted in early August, the normal harvest begins in mid-April of the following year, and the annual leaf yielding can reach 37 500-52 500 kg/ha.

Planting

The main planting methods include exclusive mulberry garden, scattered planting, intercropping and the "mulberry dike and fish pond" system.

Pure mulberry garden. Mulberry trees are planted alone in a certain area of cultivated or newly reclaimed land with a proper density for the main purpose of leaf production. This method can

achieve higher land and labour productivity by scientific measures and management. Proper planting density is one of the most important ways to increase production. Planting density depends on the variety of mulberry, soil and climatic conditions, fertilization and irrigation, etc. In Zhejiang, east China, in order to obtain 26 250 kg/ha of leaf, the recommended planting density is 10 500-15 000 plants/ha, with the trunk height 0.5-0.8 m, effective shoots 90 000-105 000, and total length of shoots 120 000 m. In Guangdong, south China, by planting in high density of 90 000-120 000 plants/ha and training into the low trunk or trunkless type, the annual leaf production can reach 37 500-52 500 kg/ha.

Scattered planting. In order to utilize fully odd pieces of land, mulberry trees can be planted at fieldsides, roadsides, around houses and along irrigation canals and so on. In Sichuan, the biggest sericulture province in China, millions of mulberry trees are scattered in hilly and mountainous areas. With this method, mulberry does not compete with other crops in cultivated land.

Intercropping. In Liaoning Province of northeast China, some

mulberry trees are intercropped with grain crops. In Zhejiang Province of southeast China, farmers get a very high profit by intercropping white chrysanthemums in mulberry gardens. In Guangdong Province of south China, winter vegetables are planted between rows of mulberry.

"Mulberry dyke and fish pond" system. This ecosystem has been developed in the Pearl River Delta of Guangdong over several hundred years. The proportion of pond area to dyke area is 6:4 or 7:3 according to conditions. Mulberry trees are planted on the dykes. After feeding the silkworms, the faeces of the larvae and the wasted leaf are used to feed fish in the pond. The pond silt is used to fertilize the mulberry trees.

Field management

Fertilization. For leaf production the proper proportion of N:P:K is 10:4:6. Generally speaking 1.5-2 kg nitrogen (equivalent to 3.26-4.35 kg urea) are needed to produce 100 kg leaf. The combined fertilizer containing proper NPK and trace elements are now

widely used for mulberry.

Irrigation. During the growing seasons of summer and autumn, 8-9 kg water will evaporate every day from 1 kg mulberry leaf. If the quantity of leaf is 7 500 kg/ha, the water transpiration will reach 72 tonnes. This does not include the evaporation from soil. In the dry season, the irrigation of water is 30 mm for an interval of five days.

Pruning and harvesting. In order to produce quality leaf for silkworm, various training, pruning and harvesting methods are adapted, according to the different climatic and geographic conditions. In tropical and subtropical areas, the main techniques include high planting density, low trunk or trunkless training types, and shoot harvesting for the whole year. In the case of animal feed production, the bush-type mulberry plantation is recommended. Mulberry seeds can be directly sown in lines with much higher density than that of silkworm feed production. The shoots and leaves can be cut several times a year by knife or machinery, so a great deal of labour can be saved.

OTHER TRADITIONAL USES

Animal feeding. In China nearly 100 percent of the mulberry cultivated is used for silkworm feeding only. The litter, containing silkworm faeces and wasted leaf, is used to feed fish in the pond or as supplementary feed for cattle.

Silkworm feeding. Mulberry contains all the necessary nutrients for the growth and development of silkworm (*Bombyx mori*). For more than 5 000 years, mulberry leaf has served as the only feed for mulberry silkworm. Even today, this has not changed in China, although the utilization of an artificial diet has achieved encouraging results in the laboratory. Fresh mulberry leaf contains 70-80 percent water, 20-30 percent DM. In the DM, CP is about 25 percent, SC 25 percent and ash 10 percent.

The leaf-silk inversion rate, or the feed efficiency of mulberry leaf for cocoon shell production, is the main index to evaluate leaf quality. In China, it takes 15 to 18 kg fresh leaves to produce 1 kg fresh cocoon at the farmer level. Researchers investigated 251

silkworm varieties maintained at the Sericulture Research Institute of the Chinese Agricultural Academy and the results showed that the leaf-silk (DM) inversion rate is 10.11 percent in average.

Fruit. The fresh mulberry fruit (sorosis) has 85 percent water, 0.36 percent CP, 1.86 percent free acid, 9.19 percent invert sugar, 0.91 percent crude fibre and 0.66 percent ash. The fruit is also rich in carotene, Vitamin B_1, B_2, C, nicotinic acid, fatty oil, etc. The main sugar is glucose, and the main free acid is malic acid. The fresh fruit is traditionally consumed. In recent years, mulberry fruit juice has been commercially produced as a healthy beverage, and become very popular in China. Without adding preservatives, the juice of the mulberry fruit can be kept fresh under cold storage for three months, while the beverage can be kept fresh at ambient temperatures for 12 months.

Mulberry tea. The DM of mulberry leaf contains rich gamma-aminobutyric acid, which is as high as 266 mg/100 g DM in an average of 119 mulberry varieties investigated, about ten times higher than that of green tea. The main function of gamma-

aminobutyric acid is to lower blood pressure and help nerve transmission. In China a certain amount of leaves are wasted by the end of the production cycle. At the end of the autumn crop, the unused leaf per hectare reaches 1500 kg or even more. In order to exploit this valuable resource, the technique of preparing mulberry tea has been developed. The processing of mulberry tea is similar to that of green tea, which includes the procedures of leaf harvesting and washing, chopping, steaming, rubbing, baking, cooling, sieving and storage. Mulberry tea is drunk in the same way as green tea.

Baked or fried mulberry tea powder is rich in protein and carbohydrate, and has a distinct fragant smell. It can be used as a food additive in the preparation of steam buns, bread, cakes and biscuits.

Edible fungi production. The dry stem of mulberry contains 50 percent cellulose, 20 percent semi-cellulose, 20 percent lignin and 5 percent CP. The proportion of carbon to nitrogen is 86:1, which is suitable for edible fungi production. By using the stem powder

of mulberry as medium, mushrooms, Jew's ear (*Auricularia auricula judae*) and medicinal fungi (*Ganoderma lucidum*) have been popularly produced in China.

Medicinal uses. China has a long history in using mulberry as a traditional herb medicine. The medicinal function of the different parts of mulberry is as follows:

- **The leaf**: It is used against hyperlidaemia and diabetes.
- **The fruit**: It is good for the liver and kidneys, and is used against nephritis, constipation, etc.
- **The root lowers** blood pressure. The bark of the root is used against pneumonia and haemoptysis.

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Mulberry cultivation and utilization in India

R. K. Datta

Central Sericultural Research and Training Institute, Central Silk Board,
Srirampura, Mysore 570 008, India.

AREA WITH MULBERRY IN INDIA

Mulberry foliage is the only food for the silkworm (*Bombyx mori*) and is grown under varied climatic conditions ranging from temperate to tropical. Mulberry leaf is a major economic component in sericulture since the quality and quantity of leaf produced per unit area have a direct bearing on cocoon harvest. In India, most states have taken up sericulture as an important agro-industry with excellent results. The total area of mulberry in the country is around 282 244 ha. The details of the area under mulberry cultivation in different states in India is shown Table 1 and also in the map.

TABLE 1

Area under mulberry in different states

State	Area (ha)
Andhra Pradesh	38 084
Assam	2 813
Jammu & Kashmir	4 717
Karnataka	166 000
Kerala	1 164
Madhya Pradesh	2 043
Manipur	*25 975
Tamil Nadu	9 491
Uttar Pradesh	5 665
West Bengal	21 358
Other	4 934

SPECIES AND VARIETIES UNDER CULTIVATION

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.

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 2.

GENERAL DESCRIPTION

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.

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.

TABLE 2

Mulberry 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	CSRTI, Mysore	Hybrid from S30 x

Victoria-1	South India Irrigated	CSRTI, Mysore	Hybrid from S66 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	CSRTI,	Triploid selection

	NE India Irrigated	Berhampore	
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

Climatic requirements

Mulberry thrives under various climatic conditions ranging from temperate to tropical located north of the equator between 28° N and 55°N latitude. The ideal range of temperature is from 24 to 28°C. Mulberry grows well in places with an annual rainfall ranging from 600 to 2 500 mm. In areas with low rainfall, growth is limited through moisture stress, resulting in low yields. On average, mulberry requires 340m^3/ha of water every ten days in case of loamy soils and 15 days in clayey soils. Atmospheric humidity in the range of 65-80 percent is ideal for mulberry growth. Sunshine is one of the important factors controlling growth and leaf quality. In the tropics, mulberry grows with a sunshine range of nine to 13 hours a day. Mulberry can be cultivated from sea level up to an elevation of 1 000 m.

Soil condition

Mulberry flourishes well in soils that are flat, deep, fertile, well drained, loamy to clayey, and porous with good moisture holding

capacity. The ideal range of soil pH is 6.2 to 6.8, the optimum being 6.5 to 6.8. Soil amendments may be used to correct the soil to obtain the required pH. The quantity of gypsum or lime to be applied in different cases to bring the pH to 6.8 are given below:

GYMPSUN:

pH range	**Gypsum/ha**
7.4 to 7.8	2.0 tonnes
7.9 to 8.4	5.0 tonnes
8.5 to 9.0	9.0 tonnes
9.1 and above	14.0 tonnes

LIME:

pH range	**Lime/ha**		
	Plain	**Hilly areas**	**Soil type**
5.5 to 6.5	1.25 tonnes	2.5 tonnes	Sandy .

2.50 tonnes	5.0 tonnes	Sandy loamy
5.0 tonnes	7.5 tonnes	Loamy
7.5 tonnes	8.75 tonnes	Clay loamy

Method of application. The powdered gypsum/lime is mixed well with garden of soil and irrigated to stagnation for 48-72 hours. Later the water is leached out by drainage and dried (suitable for ploughing and intercultivation operations).

MULBERRY CULTIVATION IN SOUTH INDIA UNDER RAINFED CONDITIONS

Suitable mulberry varieties

Kanva-2, S-13 and S-34 varieties are recommended for rainfed (rainfall: 500-800 mm) regions of South India (Karnataka, Andhra Pradesh and Tamil Nadu).

Kanva-2. Belongs to *Morus indica.* Diploid. Widely cultivated in Southern India. Selection from natural population of Mysore local

variety. Inflorescence and sorosis: female, profuse flowering, many soroses. Production characteristics: medium leaf maturity, yields about 30 to 35 tonnes/ha/year under irrigated conditions. Leaf moisture content 70 percent, protein content 21 percent and sugar content 11.5 percent. High rooting ability (80 percent) and wide adaptability. Resistant to leaf spot. Moderately resistant to leaf rust and powdery mildew.

S-13. Belongs to *M. indica*. Selection from open pollinated hybrids of Kanva-2. Recommended for rainfed areas of South India during 1990. Inflorescence: male, profuse flowering. Production characteristics: yields 8-12 tonnes/ha/year under rainfed conditions, depending on rainfall. Moisture content 70.6 percent protein content 24.3 percent and sugar content 13.8 percent. Resistant to leaf spot and powdery mildew, moderately resistant to leaf rust and tukra infestation.

S-34. Belongs to *M. indica* Diploid. Selection from progeny of S30 x Berc 776. Recommended during 1990 for rainfed areas with black cotton soils of South India. Inflorescence and sorosis:

male, profuse flowering, occasionally few soroses. Production characteristics: under rainfed conditions, yields about 15 tonnes/ha/year. Moisture content 70 percent, crude protein content 23.7 percent. Soluble sugar content 13.2 percent. Resistant to powdery mildew and leaf rust. Moderately resistant to leaf spot and susceptible to tukra infestation.

Establishment of mulberry

Land Preparation. Land for mulberry cultivation is ploughed deep with a heavy mould board plough up to a depth of 30-35 cm. Thereafter the land is repeatedly ploughed two or three times with a country plough to bring the soil to a fine tilth. The land should be properly levelled. A basal dose of welldecomposed farmyard manure (FYM) or compost is applied at the rate of 10 tonnes/ha and thoroughly incorporated into the soil.

Spacing. The spacing commonly followed for a rainfed garden is 90 x 90 cm Pits of 35 x 35 cm are prepared. About 1 kg FYM/pit should be added.

Stakes and planting. Branches of 8-10 months old and about 50 mm in diameter should be used for the preparation of stakes of 22-25 cm length with five to six healthy buds. Three stakes are planted per pit in a triangular form with a spacing of 15 cm, leaving only one bud exposed above soil surface. If planting is done with saplings, then one sapling is sufficient perpit. Planting should be done during June/July after the onset of the monsoon.

Intercultivation: During the first year, intercultivation should be done manually. Once mulberry plants are established, bullock ploughing is carried out.

Fertilization: 50N:25P:25K (kg/ha/year) in two doses. First dose: suphala (15:15:15) 167 kg, after 2 months of planting. Second dose: urea 55 kg or cam (100 kg) or ammonium sulfonate (125 kg), at end of September or early October before cessation of monsoon rains.

Pruning and leaf harvest. The first crop should be harvested six months after plantation when the mulberry is well established.

Two more crops are harvested during the first year by the leaf picking method. Mulberry should be pruned after one year at the onset of the next monsoon. Pruning is done by sharp sickle or pruning saw at a height of 25-30 cm from the ground.

Green manuring and mulching. Green manure crops can be grown as an intercrop with mulberry during the monsoon only. Green manure crops (cowpea, horse gram, *dhaincha*) should be incorporated into soil by ploughing before the flowering starts and well before the rains cease. Subsequently, plots may be mulched with any dry material or plants that will not cause needs.

Maintenance under rainfed conditions (second year onwards)

Recommended inputs (per ha per year) for gardens maintained under rainfed conditions at a spacing of 90 cm x 90 cm:

- FYM or compost, 10 tonness in a single dose at the onset of monsoon

- Azotobacter biofertilizer, 4 kg/crop, twice a year (during rainy season)
- VAM inoculum, 1 000 kg, once in mulberry lifespan (inoculation through maize rootlets)
- Suphala, 167 kg, first crop
- Single super phosphate, 156 kg, first crop
- Muriate of potash, 42 kg, first crop
- Urea (55 kg) or cam (100 kg), third crop
- Green manuring, 15 kg

Crops such as horse gram, cowpea, sun hemp and *dhaincha* should be incorporated into the soil by ploughing before flowering and cessation of the monsoon.

Leaf harvest. Individual leaf harvesting should be carried out. The expected yield (tonnes/ha/year) for different varieties is: Kanva-2, 10-12; S-13, 14-15; S-34, 14-15.

CULTIVATION IN SOUTH INDIA UNDER IRRIGATED CONDITION

Suitable mulberry varieties

Kanva-2, S-36, S-54, DD, MR-2 (especially in Tamil Nadu) and Victoria-1 varieties are recommended for irrigated conditions.

Kanva-2. Belongs to *M. indica.* Diploid. Widely cultivated in southern India after it was recommended for cultivation in 1969 by CSRTI (Mysore). Selection from natural population of Mysore local variety. Inflorescence and sorosis: Female, profuse flowering, many soroses. Production characteristics: Medium leaf maturity, yields 30-35 tonnes/ha/year under irrigated conditions. Leaf moisture content 70 percent, protein content 21 percent and sugar content 11.5 percent. Resistant to leaf spot. Moderately resistant to leaf rust and powdery mildew. High rooting ability (80 percent) and wide adaptability.

S-36. Belongs to *M. indica*. Developed at CSRTI and recommended during 1984. Evolved from Berhampore local by chemical mutagenesis. Cultivated in southern India. Moderate rooting ability. Production characteristics: yields 38-45

tonnes/ha/year under assured irrigated conditions of South India. Moisture content 76 percent, CP 22 percent and carbohydrate content 28 percent. Tolerant to leaf spot and powdery mildew. Moderately susceptible to leaf rust and to tukra infestation. Most suited to young age silkworm rearing. Sapling plantation recommended because of moderate rooting ability.

S-54. Belongs to *M. indica*. Developed at CSRTI and recommended during 1984. Selected from Berhampore local by chemical mutagenesis (EMS). Recommended for assured irrigated conditions of South India. Production characteristics: yields about 45 tonnes/ha/year under assured irrigated conditions. Highly responsive to agronomical input. Moisture content of leaf 70.5 percent, CP 23.9 percent and sugar content 13.8 percent. Moderately resistant to powdery mildew and leaf rust and resistant to leaf spot. Loses moisture very quickly. Good rooting ability.

DD. Selected from natural population of Dehra Dun variety and recommended by Karnataka State Sericultural Research and

Development Institute, Thalaghattapura. Recommended for southern India. Morphology: erect, thin branches, coarse leaves, greenish grey bark. Lower branches spreading, leaves unlobed, big size, ovate shape. Yields 35-40 tonnes/ha/year under assured irrigation conditions.

MR-2. Belongs to *M. sinensis.* Diploid. Selection from open pollinated hybrid population. Developed at CSRTI and recommended for propagation in Tamil Nadu. Mainly cultivated in Tamil Nadu under both irrigated conditions in the plains and rainfed conditions in hilly regions. Production characteristics: yields 30-35 tonnes/ha/year under irrigated conditions of Tamil Nadu. Moisture content 68 percent, protein content 23.2 percent, sugar content 13.2 percent (Fig. 7). Resistant to powdery mildew disease. Suitable for hilly areas.

Victoria-1 (V-1). Belongs to *M. indica*. Recently developed from a cross of S-30 and Berc 776 at CSRTI. Recommended during 1996 for assured irrigated conditions. Flower: male, profuse flowering, occasionally few soroses. Production characteristics:

yields about 70 tonnes/ha/year under assured irrigated conditions. Very high sprouting. Moisture content 78.9 percent and 72.5 percent in young and matured leaves respectively, protein content 24.6 percent and total sugar content 16.98 percent. Moderately resistant to leaf rust and tukra infestation and resistant to leaf spot. Quick sprouting ability and very high rooting ability (> 94 percent) high photosynthetic rate and higher water use efficiency are additional advantages. Moreover, leaves are suitable for both young and grown bivoltine silkworm rearing.

Establishment of mulberry

Selection of site. Mulberry flourishes well in soils that are flat, deep, fertile, well drained, loamy to clayey, and porous with a good moisture holding capacity. The ideal range of soil pH is 6.2 to 6.8. Mulberry can be grown in saline, alkaline and acidic soils after suitably amending the soils.

Preparation of land. Land for mulberry cultivation is ploughed deep with heavy mould board plough up to a depth of 30-35 cm.

Thereafter the land is repeatedly ploughed tw or three times with a country plough to bring the soil to a fine tilth. The land should be properly levelled. A basal dose of welldecomposed FYM or compost is applied at the rate of 20 tonnes/ha and thoroughly incorporated into the soil.

Planting. Plantations can be raised by using both cuttings and saplings. The varieties ideally suited for irrigated conditions are Kanva-2, S-36 and V-1. Branches of 6-9 months old and about 15 ml in diameter should be used for the preparation of cuttings of 15-18 cm in length with three to four healthy buds for raising in the nursery or for planting directly in the field.

Spacing. Plant spacing of 90 x 90 cm is ideal for mulberry. Two cuttings per pit to be used for direct planting. When using saplings, only one sapling/pit is necessary. A paired row plantation with spacing of (90 + 150) cm x 60 cm, is recommended.

Inter-cultivation. Two months after planting, weeding is carried

out. A second weeding is done after another two to three months. Thereafter, intercultivation should be carried out after every shoot or leaf harvest.

Irrigation. The plantation should be taken up during the onset of the monsoon to take advantage of the rain. If the rain is not sufficient, the land should be irrigated at regular intervals of 8-14 days depending on the type of soil. About one and a half to two acre inches of water is required/irrigation.

Fertilization. The total dose of fertilizer to be applied in the first year is 100 N: 50 P: 50 K/kg/ha/year. This is applied in two doses. The first dose is applied when the plantation is about two months old at the rate of 50 N: 50 P: 50 K/kg/ha. The second dose is applied after leaf harvesting at the rate of 50 kg N/ha.

Pruning. After six months of plantating, mulberry attains a height of 1.5 to 1.75 m and is ready for harvest. The first harvestíng is by bottom pruning. The second leaf harvesting is 12 weeks from the first leaf harvest and the third harvest 12 weeks from the

second harvest by shoot harvest. From the second year onwards, harvesting is done at an interval of 70 days by the shoot harvest method.

Maintenance under irrigation (second year onwards)

Spacing. 90 x 90 cm or (90 + 150) cm x 60 cm

Recommended inputs:

- FYM (20 tonnes) in two equal doses with one tonne of vermicompost
- Azotobacter (20 kg) in five equal doses
- N-triacontanol (250 ml) in two equal doses (sprays): first between 10-15 days after pruning, second, ten days after thefirst spray
- VAM inoculum (1 000 kg) One dose in plantation of lifespan (inoculation through maize as the host the plant). Not required

for plantations established with saplings inoculated with mycorrhiza

- Ammonium sulphate (750 kg), urea (325 kg) or calcium ammonium nitrate (600 kg) in five equal doses
- Single super phosphate (375 kg) in two equal split doses (crops 1 and 3)
- Muriate of potash (200 kg) in two equal split doses crops 1 and 3 days after first spray

Leaf harvest**.** Leaves are harvested either by individual leaf harvest or shoot harvesting. The latter is more economical and used for the shoot method of silkworm rearing. The expected yield (tonnes/ha/year) of varieties is Kanva-2, 32-35; S-36, 38-45; and Victoria-1, 60-70.

CULTIVATION IN HILLY AREAS

Suitable varieties

S-1, S-7999, S-1635, S-146, Tr-10 and BC-259 varieties are recommended for the hilly regions of north and northeastern India.

Establishment of mulberry

Land preparation. If the land has a gentle slope, it can be levelled by minor land shaping and providing suitable type of bunds across the slope. If the slope is greater, contour bunding terrace planting or contour line planting can be adopted. In more sloping areas, platforms for individual plants on contour lines are more suitable since this involves less soil cutting.

Spacing**.** Spacing for tree planting depends on soil topography, the extent of land available for cultivation and training method. For gentle slopes, 3´ x 3´, 5' x 5' may be adopted. In sloping more land 10' x 10' can be adopted. Pits are to be prepared for plantation. In deep textured loose soils, 45 x 45 cm and in hard shallow soils 60 x 60 x 60 cm pits are to be prepared. For each pit, 5 kg (one iron pan) of FYM or compost must be applied.

Planting**.** Saplings of five months age with five to six roots are suitable for planting during the regular onset of the monsoon. One sapling per pit should be planted. The saplings should be supported with a stick to ensure straight growth.

Maintenance. After one month, all the buds except the top five to six should be removed carefully without damaging the bark. Weeds around the plant should be removed and regular pot watering given. After three months of plantings second weeding should be done and 25 g of suphala/plant should be applied in a trench and should be covered with soil. A second dose of fertilizer (25 g urea/plant) should be applied before cessation of the monsoon. Plants must be protected from grazing.

RECOMMENDATIONS FOR HILLY AREAS (TROPICAL HIGH LAND)

Spacing. 90 x 90 cm.

Recommended inputs:

- FYM/compost (20 tonnes) in one single dose in January or February
- Azotobacter (7.5 kg) in three equal doses
- VAM inoculum (1 000 kg) in a single dose in lifespan plantation.
- Calcium ammonium nitrate (200 kg) in three equal doses
- Single super phosphate (156 kg) in two equal doses
- Muriate of potash (84 kg) in two equal doses

Since the recommendations are general, quantities of fertilizers and amendments may be applied on the basis of soil test reports.

INPUTS FOR CULTIVATION IN TEMPERATE AND SUB-TEMPERATE REGIONS

The varieties Goshoerami and China white are suitable for temperate. Chak majra and S-146 for sub-temperate regions. For Kashmir, 20 tonnes/ha/year of FYM should be applied under irrigated conditions (bush or dwarf tree) after the annual pruning in July-August, and 300:150:150 of NPK in two equal doses in

April-May and in June-July.

The expected leaf yield of these varieties is: Goshoerami and China White 15-20 tonnes/ha/year and for Chak Majra 20-22 tonnes/ha/year.

MIXED FARMING

Mulberry can be successfully grown as an intercrop (medium mixed tree) between rows of tea/coffee as shade plants. Besides providing shade, a substantial quantity of leaves can be obtained for silkworm rearing and for feeding cattle and goats. Furthermore, the pruned shoots are a good source of firewood.

Mulberry can also be grown as an intercrop for cultivation in coconut plantations. A survey has shown that mulberry is intercropped with coconut in the areas of Channapatna, Ramanagaram, Kanakapura and Bangalore in the state of Karnataka.

INSECTICIDE/PESTICIDE/FUNGICIDE AND OTHER INPUTS

The following products should be applied per ha/year, if needed, at the recommended doses:

- DDVP (Nuvan), 1.25 litres (in 480 litres of water), spray, to control tukra and leaf roller. Washing soap (non detergent), 5 kg mixed with DDVP solution (not required for leaf roller)
- Ladybird (CSRT), 625 adult beetles as biological control of mealy bug
- Bionematicide (shelf life of 180 days), 80 kg split in three doses every four months during intercultivation operations to control root knot disease
- Neen oil cake, two tonnes in four split doses every three months during intercultivation operations to control root knot disease
- Raksha (shelf life of 120 days), 1 kg for 100 plants with 50 kg FYM for root rot disease

- Bavistine (Carbendazim: a.i. 50 WP), at 0.2 percent, 1 kg dissolved in 500 litres of water and sprayed to prevent leaf spot and powdery mildew diseases

- Kavash (Choro-tholonil: a.i. WP), 1 kg dissolved in 500 litres of water and sprayed to prevent leaf rust

- Dithane M-45 (Mancozeb: a.i. 75 WP) 1 kg dissolved in 500 litres of water and sprayed to prevent leaf blight due to fungi and bacteria

- Zinc sulphate (agro grade) 4.4 kg in 440 litres of water to increase leaf quality and quantity

- Glyphosphate (agro grade) at 41 percent, 8.1 litres in two split doses (2 and 4 crop) to control weeds.

ANIMAL FEEDING PRACTICES AND OTHER TRADITIONAL USES

Mulberry is known in India as "Kalpa Vruksha" as all the parts of

the plant have many uses. It is essential to sericulture as the foliage constitutes the sole feed of the mulberry silkworm. Mulberry is a fast-growing tree which, for the convenience of sericulture practices, is maintained as a bush. It produces very large amounts of renewable biomass in the form of branches, shoots, leaves and fruit. If mulberry is used for silkworm rearing it is possible to obtain 30-35 tonnes/ha of leaf every year. By growing mulberry, a farmer obtains fodder, fuel and fertilizer. With regard to fodder for animals, farmers in India feed their cows and goats with leftover branches and leaves from silkworm rearing. Many farmers feed their animals with surplus foliage but always mix it with straw. Farmers also use the mulberry branches for fuel after pruning. Leftover twigs are allowed to dry in the garden itself. Residues of rearing are also converted to valuable FYM for mulberry gardena by putting them in a pit for four to five months prior to use. As mulberry is mainly propagated by cuttings in the tropics and sub-tropics, a certain quantity of pruned branches can be used for the preparation of cuttings and the remainder as fuel. One hectare of mulberry garden yields about 12.1 tonnes of mulberry sticks. The energy generated/ha (50 percent moisture

loss) is 27 830 Kcal (@ 4 600 calories/kg of mulberry wood). Mulberry could be exploited as an "energy crop" in cultivable, wasteland, low-lying areas, canal bunds, by roadsides and at fringe areas of the forest, etc. under various afforestation, watershed development and soil conservation programmes.

The uses of the various species of the genus *Morus* are enumerated below:

M. laevigata

The trees of this species produce sweet fruits that are used in juice and jam making in central India. In northeast India the wood is utilized as firewood; in house building and furniture making; for making stocks, spokes, poles, shafts of carriages and casts. The wood is suitable for plywood making and panelling, carving and making of toys and tea chests. It is also used for making tennis rackets. The straight log of the tree is used as a support in house-building work.

M. serrata

The wood is used for furniture making and carving, toy making, sports goods, agricultural implements and cheap types of rifles and guns.

M. alba

This species is cultivated in the hilly and plain areas of India (Himalayan region) for silkworm rearing. It is also used as a tree in roads and in social forestry. The fruit are made into juice, liquor and stews. The wood is used in the sports goods industry. It is also used for house building; agricultural implements; furniture; for making spokes, poles, shafts and bent parts of carriages and carts. The stem bark is used for making paper.

M. indica

The cultivated forms that are utilized in silkworm rearing belong to *M. indica*. There are a few profuse fruiting varieties occurring in

Maharastra and Meghalaya that can be utilized as the female parent in breeding programmes. The fruit is used for jam, jelly and juice making in Maharashtra. The pruned branches are used as fuel.

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.

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.

LEAF CHEMICAL COMPOSITION

This differs according to variety and maturity. However, on the basis of the analysis carried out at CSRTI (Mysore), the chemical composition of the leaf is as follows:

Component	Range
Moisture	65 - 78 percent
Protein	19 - 25 percent
Minerals	10 - 15 percent

Reducing sugars 1.2 - 1.9

Sugars 10 - 15 percent

MAIN PESTS AND DISEASES OF MULBERRY

Key pests of mulberry

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

Minor pests of mulberry

Thrips, jassids, scale insects, shorthorned grasshopper.

Tolerance of varieties to pests

The tukra incidence in rainfed areas was found to be maximum in the S-34 variety followed by MR-2, Berc 776, MS-7 and S-13

(Srinivas *et al*., 1996). The spread of tukra in the V-1 variety is less compared to other varieties such as Local, K-2, S-13, S-34, S-36, suggesting that the V-1 variety is relatively tolerant to tukra (Anony. 1998; Sujatha, 1997). Screening of germplasm maintained at CSRTI indicated the variety TOGHWASE - Acc. No. 257 was found to be tolerant to pest attack (unpublished data).

Main diseases of mulberry

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

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Mulberry breeding, cultivation and utilization in Japan

Hiroaki Machii, Akio Koyama and Hiroaki Yamanouchi
National Institute of Sericultural and Entomological Science
Owashi, Tsukuba, Ibaraki, Japan

GENETIC RESOURCES AND BREEDING

Species and its distribution in Japan

Mulberry belongs to the genus *Morus* of the family Moraceae. Koidzumi (1917) classified the genus *Morus* into 24 species and one subspecies. Mulberry is distributed in a wide area of tropical, subtropical, temperate and sub-arctic zones. Most mulberry

varieties cultivated in Japan belong to *M. bombysis* Koidz, *M. alba* and *M. latifolia* Poiret. Varieties belonging to *M. bombysis* are primarily cultivated in cold regions, such as the Tohoku district. *Morus latifolia* varieties are mainly cultivated in warm places, such as the Kyushu district. However, varieties of *M. alba* are cultivated in a wide area, from the Kyushu to Tohoku district, since they have middle traits of these two species. Besides these, *M. acidosa* Griff. grows naturally and is cultivated in the southwest islands, including the Okinawa islands. *Morus kagayamae* Koidz and *M. boninensis* Koidz, are indigenous to the remote islands of Hachijoujima and Ogasawara, respectively.

Ploidy of mulberry

Generally, mulberry is a diploid plant with 28 chromosomes (2n=28). However, it is rich in ploidy and many triploid varieties have been found especially among *M. bombysis* Koidz. It is said that *M. cathayana* Hemsl. has tetraploid, pentaploid and hexaploid varieties. Both *M. serrata* Roxb., indigenous to India, and *M. tiliaefolia* Makino, originally from Japan and Korea, are

known to be hexaploid. *M. boninensis* Koidz is a tetraploid that is being endangered through cross-contamination with *Morus acidosa* Griff. *M. nigra* L. is dexaploid (2n=308), the largest number of chromosomes among phanerogams.

Inflorescence of mulberry

Mulberry has different varieties with male, female or androgynous flowers. Among the varieties with androgynous flowers, there are predominantly staminated, predominantly pistillated and even hermaphrodite types. Mulberry plants with anemophilous flowers cross each other easily and naturally.

Mulberry genetic resources

The National Institute of Sericultural and Entomological Science (NISES) in Japan has collected and maintained 1 300 accessions of both indigenous and exotic origin (Machii, Koyama and Yamanouchi, 1999). In order to utilize these genetic resources efficiently in breeding programmes, morphological traits

necessary for classification and identification, agronomic traits responsible for the resistance against diseases and pests and commercial traits related to productivity and quality are investigated. Information on these traits is very useful for achieving breeding targets.

MULBERRY BREEDING METHOD

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.

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.

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.

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 (Tojo, 1985). To date, five triploid varieties, "Shinkenmochi", "Aobanezumi", "Mitsushigeri", "Yukimasari" and "Yukiasahi" have been developed and released using the polyploid breeding method.

Mulberry breeding system

In Japan, mulberry breeding started at the Government Sericultural Experiment Station in 1916, and two varieties, "Kokuso 13" and "Kokuso 70" were released to farmers in 1922. After that, with the wave of economic recovery planning after the Second World War, three varieties, "Kokuso 20", "Kokuso 21" and "Kokuso 27" were released in 1949. However, these varieties were not popularized much, despite their high leaf productivity, because they were both rather sensitive to dwarf disease, which causes the most serious growth damage, and were of slightly poor quality.

In 1958, a field trial was initiated in four climatically diverse regions (cold, snowy, temperate and warm) and 13 prefecture sericulture experiment stations. In 1971, a dwarf disease resistance test was added to the programme. When a selected strain is officially recognized to have excellent characteristics, it is commercially released as a new variety. To date, 19 varieties have been released, including "Shinichinose", "Yukishinogi", "Minamisakari", "Shinkenmochi", "Hayatesakari", "Aobanezumi", "Mitsuminami" and "Senshin". Such a system is believed to be indispensable to enable Japan's breeding network to release a new mulberry variety to farmers.

MULBERRY VARIETIES

Generally speaking, varieties belonging to *M. bombysis* have lobed and shallow bottom leaves. Branches are brown or grey, and the winter buds are oval and sharp-pointed. Varieties of *M. alba* have lobed/unlobed leaves with whitish-grey or greyish-brown branches. *Morus latifolia* varieties have large, unlobed, lustrous leaves and greenish-grey or whitish-grey branches.

"Ichinose" and "Kairyo-nezumigaeshi", most widely cultivated in Japan, are *M. alba* varieties and "Kenmochi", intensively cultivated in cold areas, is a variety of *M. bombysis*.

As mentioned above, 19 varieties were registered and released from 1971 to 1998 by the Ministry of Agriculture, Forestry and Fisheries (MAFF). Of them, six varieties, "Minamisakari", "Hayatesakari", "Mitsuminami", "Hinosakari", "Mitsusakari" and "Senshin" are suitable for warm areas such as the Kyushu and Shikoku regions. Four varieties, "Shin-ichinose", "Tokiyutaka", "Oyutaka" and "Tachimidori" are suitable for temperate areas, such as the Kanto region. Five varieties, "Shin-kenmochi", "Aobanezumi", "Mitsushigeri", "Hachinose" and "Waseyutaka" are adaptable to cold areas, such as the Tohoku region. Four varieties, "Yukishinogi", "Yukishirazu", "Yukimasari" and "Yukiasahi" are adaptable to snowy areas, such as Niigata prefecture. There are some varieties, such as"Hayatesakari", which have been dispersed into the Tohoku from the Kyushu area, which was their place of origin.

PHYSIOLOGY AND CULTIVATION OF MULBERRY

Leaf production

The growth of mulberry is generally divided into three stages: new shoot development, growth and storage (Ohyama, 1970). 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.

NUTRITIVE VALUE OF MULBERRY LEAVES

The silkworm eats only mulberry leaves to make its cocoon,

producing silk. Mulberry leaves are rich in protein and amino acids (see Table; Machii, 1989). 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 (see figure; Machii and Katagiri, 1991). Therefore, an increase in the protein level of mulberry leaves may lead to improvements in cocoon productivity.

Relationship between mulberry leaf protein content and the cocoon shell yield in spring and autumn

Cultivation

According to the 1996 statistical data of Japanese sericulture, the area of mulberry gardens was 14 884 ha, including 1 172 ha of densely planted fields. Regarding planting density of mulberry gardens, normal planting with 600-1 000 plants per 10 ha is common. In densely planted fields, aiming at early high yield and machinery harvesting, more than 2 500 plants/10 ha are used.

Standard application of chemical fertilizer to mulberry garden is 30 kg of N, 14 kg of phosphate and 12 kg of potassium/10 ha for alluvial soil, and 30 kg of N, 16 kg of phosphate and 20 kg of potassium/10 ha for volcanic ash soil. In either case, application of at least 1 500 kg of compost per 10 ha is recommended.

Amino acid content in mulberry leaf (mean of 119 varieties) and minimum requirement for silkworm (mg/g DM)

Amino acid	Content	(%)	SD	CV	Minimum requirement for silkworms*
Asp	20.49	(10.0)	3.63	17.72	
Thr	10.52	(5.2)	1.75	16.63	7
Ser	10.12	(5.0)	1.60	15.79	
Glu	23.23	(11.3)	3.96	17.03	
Pro	10.93	(5.4)	3.73	34.10	
Gly	12.02	(5.9)	1.95	16.22	
Ala	15.75	(7.7)	2.90	18.44	

Val	12.83	(6.3)	2.17	16.92	8
Cys	1.17	(0.6)	0.25	21.72	
Met	2.99	(1.5)	0.61	20.48	4
Ileu	10.04	(4.9)	1.88	18.68	8
Leu	19.45	(9.5)	3.10	15.93	8
Tyear	7.40	(3.6)	1.39	18.74	
Phe	12.26	(6.0)	2.06	16.78	8
GABA	2.26	(1.1)	0.69	30.70	
NH3	2.89	(1.4)	0.54	18.70	
Lys	12.33	(6.0)	2.58	20.91	8
His	4.61	(2.3)	0.82	17.78	5
Arg	12.96	(6.3)	2.72	20.95	8
Total	204.25	(100.0)			
N(percent)	4.36		0.42	9.63	

*Arai and Ito, 1967.

TRAINING AND 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.

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.

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.

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:

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.

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.

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.

Mushroom production

Mulberry stem and stem powder are found to be a good source of media for mushroom production.

Animal feed

The use of mulberry for animal production in Japan is being reported in other articles in this E-conference.

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Mulberry germplasm and cultivation in Brazil

José Eduardo de Almeida and **Tamara Canto Fonseca**
Instituto de Zootecnia, São Paulo, Brazil

INTRODUCTION

Mulberry (*Morus* sp.), originally from Asia, was introduced in Brazil during colonial times. Today, mulberry is widely known and is common in orchards, recreational rural households and gardens. Its fruit is appreciated for direct consumption and for making jam. However, commercial mulberry cultivation occurs only in regions where it is associated with sericulture.

According to the latest statistics, the mulberry area in Brazil covers approximately 38 000 ha (Table 1 and Figure 1). The state of Paraná is the largest concentration of that area with 32 400 ha

(Table 2 and Figure 2), followed by the western portion of the state of São Paulo, with 4 600 ha (Table 3 and Figure 3) and by smaller areas in the states of Goiás, Mato Grosso do Sul, Minas Gerais and Santa Catarina.

It must be highlighted that all production of these areas is for the silkworm, and no surplus is available for other uses. Plant management includes frequent pruning which prevents plants from blossoming and fruit development; plant sex is thus irrelevant.

According to Fonseca and Fonseca and Shammass (1986), the first attempt to cultivate mulberry commercially occurred in state of Rio de Janeiro, as an initiative of the Emperor D. Pedro II, in the middle of nineteenth century. After a period of decadence, it was resumed only in 1923, in the eastern parts of the state of São Paulo State following Italian immigration. Later, eastern São Paulo showed a decline in sericulture and western São Paulo flourished, coinciding with Japanese immigration. Today, sericulture is concentrated in the northern part of Paraná State.

TABLE 1

Areas with mulberry

States	Area (ha)
Goiás (GO)	24
Mato Grosso do Sul (MS)	459
Minas Gerais (MG)	77
Paraná (PR)	32 426
Santa Catarina (SC)	114
São Paulo (SP)	4 645
TOTAL	37 745

Source: Abrasseda, 1998.

Figure 1. Map of Brazil

Figure 2. State of Paraná State

TABLE 2

Mulberry area in the state of Paraná by county

County	Area (ha)
Apucarana	610
Campo Mourão	1 244
Cascavel	1 929
Cornélio Procópio	91
Curitiba	151
Francisco Beltrão	662
Guarapuava	214
Irati	1
Ivaiporã	2 241
Londrina	630
Maringá	8 776
Paranavai	4 601

Pato Branco	502
Ponta Grossa	415
Santo Antônio Da Platina	1 970
Toledo	763
Umuarama	7 626
Total	32 426

Source: EMATER, 1998.

Figure 3. Figure of São Paulo

TABLE 3

Mulberry area in the State of São Paulo

Regional agricultural division	Area (ha)	Regional agricultural division	Area (ha)
Andradina	243	Jaú	43

Araçatuba	27	Limeira	18
Araraquara	67	Lins	899
Assis	126	Marília	319
Avaré	21	Ourinhos	161
Bauru	554	Piracicaba	16
Catanduva	78	Presidente Prudente	222
Dracena	236	Presidente Venceslau	49
General Salgado	447	São João da Boa Vista	35
Itapetininga	5	São José do Rio Preto	194
Itapeva	42	Tupã	775
Jaboticabal	2	Votuporânga	30
Jales	36	Total	4 645

Source: Abrasseda, 1998.

The causes that determined the movements of mulberry cultivation are not clear, but they must be related to various

factors such as low income conditions prevailing among the rural population that sees sericulture as a secure source for income generation; the appearance of other economic alternatives; and soil exhaustion, production and profitability decline, resulting in sericulture opening space to other activities with more intensive in capital requirements.

IMPROVED VARIETIES AND CLONES

In Brazil, all cultivated mulberry varieties appear to belong to *M. alba*. In São Paulo state, there is an active germoplasm bank (BAG) at the Estação Experimental de Zootecnia (Livestock Experimental Station) in Gália county; one collection at the University of São Paulo (UNESP) in Jaboticabal county; one in a spinning mill (under the trade name of Fiações de Seda Bratac) in Bastos county; and one at the Agronomic Institute of Paraná (IAPAR), in Londrina.

The Estação Experimental de Zootecnia has sericulture research as a mandate and its BAG includes three collections: variety

collection (32 clones), the Instituto de Zootecnia collection (42 clones); and the Fukashi-Miura collection (14 clones).

Little information is available on which clones are used in the 38 000 ha planted with mulberry. Commercial companies have disseminated the Miura and Korin clones, because of the great supply of planting material. These clones together with the Calabresa variety, make up the large majority of the cultivated area.

Genetically modified clones (IZ and FM) are very productive and with more nutritious leaves but, being destined completely to silkworm feeding, their expansion has been limited.

Production data for this report were obtained from research carried out at the Instituto de Zootecnia (Fonseca, Fonseca and Paolieri, 1985a, 1985b, 1985c; Fonseca, Fonseca Schammass, 1986, 1987a; Fonseca *et al*., 1987b and 1987c). Since the purpose of the work was fresh biomass production for silkworm feeding, the data are in fresh leaf weight. However, according to

Almeida *et al*. (1989), it is known that the leaf:stem ratio is 1:1 when the cut is made at 90 days. For more frequent cutting, leaf:stem ratio can vary.

VARIETY COLLECTION

Branca da Espanha (Spanish white). Imported from Spain. It shows good development, good adaptation, is productive and precocious. Good propagation through cuttings.

Calabresa. Imported from Italy. Optimal adaptation. It is productive, rustic and very precocious. Easy propagation through cuttings. Estimated production is 5 079 kg/ha/year.

Catânia 1. Imported from Italy. Well adapted, vigorous and very productive. Not well propagated through cuttings.

Catânia 2. Imported from Italy. Well adapted, vigorous and highly productive. Not well propagated through cuttings.

Catânia Paulista. From the former Livestock Experimental Station

at Limeira, São Paulo State. Its characteristics have some resemblance to the first two Catania varieties above. It is precocious, productive and vigorous. Not well propagated through cuttings.

Contadini. Imported from Italy. Well adapted, productive and precocious. Very good propagation through cuttings.

Fernão Dias. From Fernão Dias county of São Paulo state. It is precocious and productive. Good propagation through cuttings. Estimated production is 5 302 kg/ha/year.

Flório. Italian origin. Not very well adapted. It is precocious but not productive. Not well propagated through cuttings.

Formosa. Originated from Taiwan. Very well adapted, productive, precocious and vigorous. Easily propagated through cuttings. Estimated production is 8 608 kg/ha/year.

Galiana. Originated from Livestock Experimental Station at Gália, São Paulo state. Medium tardy, vigorous and rustic. Not well

propagated through cuttings. Data for 1 m branch: leaf number, 22; mean leaf weight, 5.86 g; mean stem weight, 53.1 g; leaf weight:stem weight, 2.43; internodal distance 4.5 cm.

Iamada. Originated from Promissão county, São Paulo state. It is precocious, but not productive. Good propagation through cuttings.

Kokuso 21. Imported from Japan. Not well adapted, tardy, produces few branches that grow slowly. No propagation through cuttings.

Kokuso 27. Imported from Japan. Not well adapted, tardy, produces few branches that grown slowly. No propagation through cuttings.

Lopes Lins. Originated from Tietê county, São Paulo state. It is precocious and productive. Good propagation through cuttings.

Miura. Originated from Bastos county, São Paulo State. It has some similar characteristics to the Calabrese variety. It is

precocious, rustic and productive.

Moretiana. Imported from Italy. Very good adaptation, productive and rustic. It is a little tardy, no propagation through cuttings.

Moscatela. Originated from Italy. Good adaptation, precocious, rustic and productive. Good propagation through cuttings.

Nezumigaeshi. Imported from Japan. Good adaptation, productive, rustic and vigorous. Not well propagated through cuttings.

Nostrana. From the former Livestock Experimental Station at Limeira, São Paulo state. It is rustic, precocious and vigorous. Easy propagation through cuttings.

Paduana. Originated from Borborema county, São Paulo state. It is precocious, rustic and productive. Good propagation through cuttings.

Pêndula. Originated from Rio de Janeiro State. It is precocious,

rustic but not productive.

Rosa. Originated from Italy. Good adaptation but low productivity. Slow development. Good propagation through cuttings.

Rosa da Lombardia. Originated from Italy. Bad adaptation, its medium tardy, low productivity. Slow development and precocious leaf maturation. Not good propagation through cuttings.

Rosol. Originated from Registro county, São Paulo. It is precocious, rustic, vigorous and productive. but leaves are very wrinkled, coarse and easily broken, little adapted to feeding the silkworm.

Selvagem. From the former Sericulture Service at Campinas, São Paulo state. It is rustic, vigorous and precocious, showing low productivity, with excessively multilobed leaves and reduced useful foliar area.

Serra-das-Araras. Coming from the mountain Araras range situated in Rio de Janeiro state. It is very precocious, rustic and

with low production. Very intense blossoming. Easy propagation through cuttings.

Siciliana. Coming from Barbacena county, Minas Gerais state, It is precocious, rustic but with low production. Easily propagated through cuttings.

Talo Roxo. From the former Sericulture Service in Campinas, São Paulo state. It is precocious, with low production, and easy propagation through cuttings.

Tietê. Coming from Tietê county, São Paulo state. It is precocious, rustic and with low production. Good propagation through cuttings.

Ungaresa - From the former Livestock Experimental Station at Limeira, São Paulo state. It is rustic, precocious and productive. Leaves are coarse, not appreciated by silkworm.

Korin. From the Fiações de Seda Bratac collection, it is very vigorous and productive. Good propagation through cuttings.

The production and agrobotanic characteristics of the varieties above are shown in Tables 4 and 5.

TABLE 4

Quantitative characteristics of some mulberry varieties (data for 1 m branch)

Variety	Leaf #	Leaf weight (g)	Branch weight (g)	Leaf/branch ratio	Internodal length (cm)
Branca da Espanha	24	4.65	42.5	2.63	4.2
Calabresa	26	3.04	33.5	2.36	3.8
Catânia 1	26	5.79	64.3	2.35	3.8
Catânia 2	26	6.09	50.9	3.10	3.8
Catânia Paulista	25	5.44	61.8	2.20	4.0
Contadini	31	3.29	38	2.69	3.2

Fernão Dias	25	4.10	38.6	2.67	4.0
Flório	25	2.40	37.5	1.60	4.0
Formosa	24	4.66	41.5	2.70	4.2
Galiana	22	5.86	53.1	2.43	4.5
Iamada	30	2.52	52.7	1.14	2.8
Kokuso 21	31	7.29	75.1	3.01	3.2
Kokuso 27	30	7.88	75.0	3.15	3.3
Lopes Lins	19	5.30	41.9	2.41	5.2
Miura	24	4.24	38.4	2.66	4.2
Moretiana	33	2.67	46.8	1.88	3.3
Moscatela	24	3.91	31	3.04	4.2
Nezumigaeshi	47	3.54	65.1	2.55	2.1
Nostrana	21	4.23	30.9	2.88	4.8
Paduana	20	8.04	44.6	3.61	5.0
Pêndula	24	3.48	32.2	2.61	4.2
Rosa	28	2.47	35.6	1.91	3.6

Rosa da Lombardia	31	4.29	62.2	2.14	3.2
Rosol	16	9.05	44.1	3.29	6.2
Selvagem	21	2.68	25.0	2.24	4.8
Serra-das-Araras	42	1.98	34.5	2.44	2.4
Siciliana	23	3.17	29.5	2.48	4.3
Talo Roxo	24	3.95	40.1	2.37	4.2
Tietê	21	4.75	43.1	2.32	4.8
Ungaresa	26	2.95	32.3	2.39	2.8
Korin	-	-	-	-	-

TABLE 5a

Agrobotanic characteristics of some mulberry varieties

Variety	Size	Shape	Base	Edge[1]

	(cm^2)			Edge
B. da Espanha	380	Entire/Lobed	Truncate	S
Calabresa	240	Five lobed	Lobed	D
Catânia 1	330	Entire/Ovate	Truncate	D
Catânia 2	335	Entire/Ovate	Truncate	D
Catânia Paulista	252	Entire/Ovate	Rounde	D
Contadini	257	Entire/Ovate	Rounde	D
Fernão Dias	274	Entire/Ovate/Lobed	Cordate	D
Flório	150	Entire/Cordiform	Cordate	S
Formosa	339	Entire/Ovate/Lobed	Cordate	S
Galiana	405	Lobed	Truncate/Lobed	S
Iamada	184	Entire/Ovate/Lobed	Cordate/Lobed	D
Kokuzo 21	408	Entire/Ovate	Linear round	C
Kokuzo 27	405	Intire/Ovate	Round	C

Lopes Lins	330	Entire/Lobed	Cordate	C
Miura	276	Entire/Lobed	Cordate/Lobed	D
Moretiana	181	Entire/Cordiform	Cordate	S
Moscatela	282	Entire/Ovate	Truncate	S
Nezumigaeshi	213	Five lobed*	Truncate/Lobed	S
Nostrana	250	Entire/Ovate	Rounded	D
Paduana	404	Entire/Ovate/Lobed	Cordate	D
Pêndula	232	Entire/Ovate/Lobed	Truncate/Linear	D
Rosa	177	Entire/Cordiform	Cordate	D
R. da Lombardia	289	Entire/Cordiform	Deeply cordate	S
Rosol	500	Entire/Ovate	Linear	D
Selvagem	210	Lobed	Lobed	S/D
Serra das Araras	144	Entire/Ovate	Cordate	S
Siciliana	253	Entire/Ovate/Lobed	Truncate	S/D

Talo Roxo	282	Entire/Cordiform	Cordate	D
Tietê	272	Entire/Ovate/Lobed	Truncate	D
Ungaresa	209	Entire/Ovate	Truncate/Linear	S/D
Korin	-	-	-	-

C = crenated; D = dentated; [1] S = serrated.

TABLE 5b

Agrobotanic characteristics of some mulberry varieties

Variety	**Surface**	**Bark colour**	**Bud[1]**	**Flower**	**Size[1]/Colour**
B. da Espanha	Smooth/Glossy	Greyish-yellow	S	♀	S/White
Calabresa	Smooth/Glossy	Dark greyish brown	S	♀	M/Purple

Catânia 1	Undulated/Glossy	Light greyish yellow	S	♀	L/Purple
Catânia 2	Undulated/Glossy	Light brown	M	♀	L/White
Catânia Paulista	Undulated/Glossy	Whitish brown	L	♂	-
Contadini	Undulated/Glossy	Greyish brown	M	♀	M/Purple
Fernão Dias	Smooth/Glossy	Whitish brown	M	♀	M/Purple
Flório	Smooth/Glossy	Brown	S	♀	S/Purple
Formosa	Smooth/Glossy	Dark brown	M	♀	M/Purple
Galiana	Smooth/Glossy	Greyish brown	L	♀	M/Purple
Iamada	Smooth/Glossy	Greyish	M	♀	M/Purple

		brown		♂+	
Kokuso 21	Smooth/Glossy	Light greyish yellow	M	♂	-
Kokuso 27	Smooth/Glossy	Light greyish yellow	S	♂	-
Lopes Lins	Smooth/Glossy	Light greyish brown	S	♀	S/Purple
Miura	Smooth/Glossy	Light greyish brown	L	♀	M/Purple
Moretiana	Smooth/Glossys	Brown	M	♀	S/Purple
Moscatela	Smooth/Glossy	Light brown greyish	L	♀	S/Purple
Nezumigaeshi	Smooth/Glossy	Light	S	♂	-

		yellow			
Nostrana	Undulated/Glossy	greyish Dark brown	M	♀	M/Purple
Paduana	Undulated/Opaque	Greyish brown	L	♂	-
Pêndula	Smooth/Glossy	Greyish brown	L	♀	M/Purple
Rosa	Smooth/Opaque	Brown	M	♀	S/Purple
R. da Lombardia	Smooth/Glossy	Light brown	S	♀	M/Purple
Rosol	Blistered	Whitish brown	S	♀	S/Purple
Selvagem	Smooth/Glossy	Dark brown	L	♀	M/Purple
Serra-das-Araras	Smooth/Glossy	Brown	L	♀	S/Purple
Siciliana	Undulated/Glossy	Dark	L	♂	-

		brown			
Talo Roxo	Undulated/Opaque	Dark reddish brown	L	♀	L/Purple
Tietê	Smooth/Glossy	Brown	M	♀	M/Purple
Ungaresa	Smooth/Opaque	Dark brown	S	♂	-
Korin	-	-	-	-	-

[1]S = small; M = medium; L = large.

TABLE 6

Origin and estimated production of IZ collection clones

Clone	Cross-breeding	Estimated production (kg/ha/year)
IZ 30	Random breeding	8 559

IZ 40	Random breeding	9 931
IZ 64	Random breeding	7 945
IZ 1/17	Fernão Dias x Catânia Paulista	7 686
IZ 2/2	Calabresa x Catânia Paulista	6 197
IZ 3/2 - Issaokina	Contadini x Catânia Paulista	8 597
IZ 5/2 - Capucho	Branca da Espanha x Catânia	7 895
IZ 6/2	Lopes Lins x Catânia Paulista	5 438
IZ 10/1 - Campinas	Lopes Lins x Catânia Paulista	7 984
IZ 10/4	Lopes Lins x Catânia Paulista	6 698
IZ 12/3	Fernão Dias x	6 104

IZ 13/6 - Luiz Paolieri	Catânia Paulista x Kokuso	11 844
IZ 15/1	Calabresa x Nezumigaeshi	6 304
IZ 15/7 - Rio da Pedras	Calabresa x Nezumigaeshi	6 501
IZ 19/1	Talo Roxo x Kokuso 27	5 119
IZ 19/13 - Rosa da Fonseca	Talo Roxo x Kokuzo 27	10 177
IZ 23/8	Rosol x Catânia Paulista	5 555
IZ 29/1 - Sempre Verde	Capinas x Nezumigaeshi	8 224
IZ 42/12	Catânia x Siciliana	5 001
IZ 51/1	B. da Espanha x Nezumigaeshi	7 878
IZ 56/4 -	Formosa x Catania	12 043

Tamarina	Paulista	
IZ 57/2 - Javanesa	Fromosa x Kokuso 27	9 353
IZ 1/1,/2,/3,/12 &/16	Fernão Dias x Catânia Paulista	
IZ 2/1	Calabresa x Catânia Paulista	
IZ 3/1	Contadini x Catânia Paulista	
IZ 4/1 & IZ 1/4	Moretiana x Catânia Paulista	
IZ 5/1 & IZ 6/1	Calabresa x Catânia Paulista	
IZ 6/3 & IZ 9/7	Lopes Lins x Catânia Paulista	
IZ 11/9	Formosa x Kokuso 21	4 526

IZ 14/1	B. de Espanha x Catânia Paulista	
IZ 16/3	Fernão Dias x Catânia Paulista	5 310
IZ 18/19	Catânia x Catânia Paulista	
IZ 23/3	Rosol x Catânia Paulista	4 049
IZ 23/3	"	

INSTITUTO DE ZOOTECNIA COLLECTION

This is a collection of selected clones, originating from breeding programmes at the Instituto de Zootecnia (IZ), Secretary of Agriculture of São Paulo state (Table 6). The production and agrobotanic characteristics of the IZ clones are shown in Tables 7 and 8.

TABLE 7

Quantitative characteristics of mulberry clones of the IZ collection (data per 1 m -branch)

Clone	Leaf number	Leaf weight (g)	Branch weight (g)	Leaf/branch ratio	Internodal length (cm)
IZ 30	27	2.52	35.0	1.70	3.71
IZ 40	34	2.35	49.0	2.35	2.95
IZ 64	26	4.70	38.0	3.00	3.85
IZ 1/17	19	5.28	48.9	2.05	5.3
IZ 2/2	24	3.06	49.9	1.47	4.2
IZ 3/2	27	4.10	49.9	2.22	3.7
IZ 5/2	24	4.13	46.3	2.14	4.2
IZ 6/2	22	4.09	48.6	1.85	4.5
IZ 10/1	22	5.56	46.8	2.62	4.5
IZ	23	4.26	53.7	1.82	4.3

IZ 10/4	23	4.26	53.7	1.82	4.3
IZ 10/8	19	4.27	38.0	2.14	5.3
IZ 12/3	25	3.88	41.9	2.32	4.0
IZ 13/6	25	4.82	53.0	2.28	4.0
IZ 15/1	25	3.74	52.1	1.80	4.0
IZ 15/7	26	1.83	34.6	1.83	3.8
IZ 19/1	28	3.10	50.7	1.71	3.6
IZ 19/13	32	4.06	54.9	2.37	3.1
IZ 23/8	23	5.62	52.9	2.44	4.3
IZ	28	3.57	48.0	2.08	3.6

IZ 29/1	28	3.57	48.0	2.08	3.6
IZ 42/12	22	3.34	37.4	1.97	4.5
IZ 51/1	21	3.89	35.5	2.30	4.8
IZ 56/4	23	4.24	49.4	1.97	4.3
IZ 57/2	25	4.16	44.2	2.35	4.4

FUKASHI MIURA COLLECTION

Mulberry clones selected by Fukashi Miura (FM) from Fiações de Seda Shoei-Bratac, São José do Rio Preto, São Paulo state:

Shima Korin 01-SK02-SK03-SK04 - from crossbreeding Shimagoa and Korin varieties.

Shima Miura 11-SM12-SM13-SM14-SM15 - from crossbreeding Shimagoa and Miura varieties.

Fukashi Miura 3/1-FM6/3-FM10-FM30-FM3/2 - from selection into plant origin by seed.

TABLE 8

Agrobotanic characteristics of mulberry clones from the IZ collection

Clone	Size (cm^2)	Shape	Base	Edge[1]	Surface
IZ 30	235	Entire/Ovate	Truncate/Round	S	Plan
IZ 40	265	Entire/Cordiform	Truncate	S	Plan
IZ 64	395	Entire/Ovate	Cordate	D	Undulate
IZ 1/17	332	Entire/Ovate	Cordate	C	Undulate
IZ 2/2	236	Entire/Ovate	Cordate	S	Undulate

IZ 3/2	246	Entire/Ovate	Cordate	S	Undulate
IZ 5/2	271	Entire/Cordiform Lobed	Cordate	S	Undulate
IZ 6/2	230	Entire/Cordiform Lobed	Deep cordate	C	Wrinkled
IZ 10/1	301	Entire/Cordiform Ovated	Cordate	C	Undulate
IZ 10/4	241	Entire/Ovate	Cordate	C	Undulate
IZ 10/8	396	Entire/Ovate	Deep cordate	S	Undulate
IZ 12/3	261	Entire/Ovate	Cordate	S	Undulate
IZ 13/6	242	Entire/Ovate Lobed	Cordate/Lobed	D	Undulate
IZ 15/1	309	Five-lobed	Lobed	S	Plan

IZ 15/7	200	Entire/Ovate Lobed	Cordate	S	Plan
IZ 19/1	308	Entire/Cordiform	Cordate	C	Plan
IZ 19/13	332	Entire/Ovate	Truncate	C	Undulate
IZ 23/8	222	Entire/Cordiform	Cordate	D	Wrinkled
IZ 29/1	201	Asymmetric/Cordiform	Deep cordate	S	Plan
IZ 42/12	230	Entire/Ovate	Truncate	C	Plan
IZ 51/1	334	Entire/Ovate	Cordate	S	Rugose
IZ 56/4	339	Entire/Cordiform	Cordate	S	Undulate
IZ 57/2	365	Entire/Cordiform	Truncate	S	Plan

C = crenated; D = dentated; S = serrated.

CULTIVATION

Climatic conditions

Temperature. Optimal temperature required for mulberry is situated between 24-28ºC; below 13^{O}C growing stops and so do branching and bud formation. From August to May, mulberry vegetative growing is practically continuous.

Rainfall. Ideal rainfall for mulberry This condition is met in São Paulo and Paraná states.

TABLE 8

Agrobotanic characteristics of clones from the IZ collection

Variety	Bark colour	Bud[1]	Flower	VR %[2]

IZ 30	Greenish ligth brown	S	♀	80
IZ 40	Greyish light green	M	♀	86
IZ 64	Greyish light brown	L	♀/♂*	54
IZ 1/17	Geryish brown	S	♀	-
IZ 2/2	Greyish light green	M	♀	-
IZ 3/2	Whitish light green	L	♀	-
IZ 5/2	Geennish brown	M	♂	-
IZ 6/2	Greyish brown	M	♀	-
IZ 10/1	Greyish light brown	M	♀	-
IZ 10/4	Greyish green	M	♀	-
IZ 10/8	Greyish brown	M	♀	-
IZ 12/3	Yellowish brown	M	♂	-
IZ 13/6	Whitish dark brown	L	♂	-
IZ 15/1	Greyish dark brown	L	♂	-

IZ 15/7	Greyish light brown	S	♀	-
IZ 19/1	Greenish dark brown	L	♀	-
IZ 19/13	Whitish light green	L	♀	-
IZ 23/8	Greenish light brown	L	♀	-
IZ 29/1	Greenish light green	L	♀	-
IZ 42/12	Greenish light green	L	♀	-
IZ 51/1	Greenish light brown	M	♀	-
IZ 56/4	Greenish light green	L	♀	-
IZ 57/2	Greenish light brown	M	♀	-

S = small; M = medium; L = large[2] VP percent = percentage of vegetative propagation.

Relative humidity. In general, the required air humidity for

mulberry is between 65 and 80 percent. Higher precipitation and soil humidity are contributing factors towards improved leaf quality.

Photoperiod. The major mulberry areas in Brazil are located between 20 and 30^{o} south, and it seems that there are no photoperiodic limitations to plant growing.

Altitude. In São Paulo State, in general, mulberry crops are located in altitudes varying from 300 to 700 m, far from the limit tolerated by mulberry.

Drought resistance. No research data are available relating to drought resistance for varieties cultivated in Brazil. The seasonal supply of green leaves shown by some varieties even in drought periods was qualitatively observed for some clones, such as IZ 29/1.

Soil

Despite mulberry's need for adequate soil quality, it can grow in most of the soils available in São Paulo state. However, shallow soils and well as compacted, hard, impermeable and swampy soils should be avoided. Whenever possible, preferred soils are deep, fertile, well-drained, friable, porous, with adequate water retention capacity and a mild acidity (pH 6.2-6.8).

Fertilization

Organic. In general, poultry manure is applied, with a minimum dose of 0.5 kg per plant, during the winter time, at a depth of 20 to 30 cm. Field experiments demonstrate higher productivity when mulch is applied to mulberry plants. When available, its utilization is highly desirable, but some precautions are necessary. For example, when residues of different origins with very high C/N ratio are used, it is recommended that chemical N fertilizer be applied jointly in order to accelerate the decomposition of organic material and avoid competition for N in the soil.

TABLE 9

Mineral content of organic materials

Material	C	N	P	K	Ca	Mg	S	Zn	Cu	Cd	Ni	Pb
Fresh bovine manure	100	5	2.6	6	2	1	1	33	6	-	2	2
Composted bovine manure	320	15	12	21	20	6	2	217	25	-	2	1
Poultry manure	140	14	8	7	23	5	2	138	14	2	2	17
Swine manure	60	7	2	5	12	3	-	242	264	-	2	3
Castor oil seed meal	450	45	7	11	18	5	-	128	73	-	-	-
Mucuna	60	3	0.6	3	2	0.4	-	6	3	-	-	-
Crotalaria juncea	70	2.8	0.4	3	2	0.4	-	2	1	-	-	-

Source: Van Raij *et al*., 1996.

Chemical fertilizers. According to the literature, there is no consensus on the ideal chemical fertilizer for mulberry. Among other factors, quantities will obviously depend on soil fertility. Soil

analyses have been the most viable and practical way to evaluate soil fertility. Although there are no guidelines on the amount of fertilizer for mulberry according to soil fertility and economic factors, it is suggested that the table of Bulletin 100 from Instituto Agronômico de Campinas (Van Raij, *et al*. 1996).

According to Rubia Brasil Sobrinho and Azeredo (1976), in cases of low contents in P and K and when all silkworm residues are applied to mulberry fields, the following application could be suggested (in kg/ha/year): 250 kg of N, 65 kg of P2O5, and 156 kg of K2O.

In manure utilization, the data presented in Table 9 may help to determine nutrient application rates.

DISEASES AND PESTS

The characteristics and symptoms of the main mulberry pests and diseases are described in the Sericulture Manual (Manual de Sericicultura) compiled by the Technical Committee on Sericulture

(Comisso Técnica de Sericicultura) (Tinoco, 1999).

PRINCIPAL PESTS

Pseudaulacaspis pentagona (Targ. Tozz, 1885). This insect attacks mulberry branches and stems, introducing its mouth apparatus (stylus) into the sap plant conductors and sucking a great deal of the plant sap. These insects shield themselves under small structures and, when an attack is intense, these structures fully cover the branches and stems of the plant (Figure 4). The plant is quite weakened by the attack, showing cracks that allow the entrance of pathogenic micro-organisms. In boggy, shadowed and poorly aired soils, or in badly managed crops, this attack is more severe.

Figure 4 Mulberry branches infested by *Pseudaulacaspis pentagona*

Naupactus spp. These beetles belong to the Curculionidae family. Adult phases of the insect feed on mulberry leaves, causing

severe reduction in the leaf surface, and larvae phases feed on roots. As a result, plant vigour decays, once nutrient absorption collapses and pathogenic micro-organisms are eased through plant injuries. The *Naupactus versatilis* form has been more frequently detected in Paraná state. Its adult form presents a length ranging from 11 to 14 mm, with a metallic green colour, which becomes darker with age, due to the loss of scale-like structures.

Adult form of *Naupactus versatilis*

Migdolus fryanus Westwood-Coleoptera from the Cerambycidae family. This polyphagous beetle, biologically little known, has been causing economic damages in several crops, namely in sugarcane and, more recently, in mulberry. Adult males are generally black, dark brown or red brown, and their total length ranges from 12.1 to 37.0 mm. Adult females, on the other hand, are generally reddish brown or dark brownish, and their total length ranges from 19.5 to 35 mm (Bento *et al*., 1995). The male exemplars have membranous and functional wings, with antennas that

reaches approximately half the body size (Figure 6). The females have reduced non-functional wings and much shorter antennae than the males. Larvae cause the totality of the damage to the mulberry plants. Those larvae find their ideal source of nutrition in the root system, so destroying the roots (Figure 7). Insect dispersion happens in the larvae phases, because in this period an increased mobility in the soil environment is observed, establishing a net of channels that are likely to be used for adults in order to reach the soil surface during the mating period. Although plants are generally affected only partially, attacks can completely destroy the affected plants.

Figura 6 Adult form of *Migdolus fryanus*

Figure 7 Mulberry root with lesions caused by *Migdolus fryanus* larvae

With regard to population control of the insecto, there are few solutions because of its biological and behavioural aspects. One obstacle is that larvae bury 3-4 m into the soil; eggs are laid atg

different depths. Although there was a generalized belief that attacks were more frequent in sandy soils, today studies on the subject have demonstrated that there is no linkage between types of soil and *Migdolus* attack.

"Cutting-prone" ants - Sauba ant. Ant hills are true subterranean urban structures, endowed with a great number of individuals (more than ten million, in a adult ant hill), which can reach 7 m in depth, below the soil line. Quenquéns ants of the genus *Acromyearmex* are smaller than sauba ants and, in general, ant hills from this genus hardly reach depths lower than 50 cm. One ant hill communicates with another by ocelli (orifices on the soil surface). In an ant hill of three or more years old, three types of ocelli are observed: one for transportation of land, one for ventilation, and one for food provision.

Nematode diseases - *Meloidogyne* spp. These worm species attack mulberry producing root tumours (root knots), which make it hard for the plant to absorb nutrients and water causing severe damage to the crop (Figure 8). Plants attacked present reduction

in size, with leaves appearing to lack water, becoming yellower and collapsing, reducing sensibly the production of leaves per area. Mulberry vitality deteriorates gradually and, in the later stages, the plant dies.

Figure 8 Mulberry root with root-knots

Main bacteria and fungus diseases

White root rot. This is caused by fungus from genus *Rosellinia*. This type of fungus lives as a saprophyte in decaying organic matter, mainly from plants left over the soil, and they can become pathogenic to cultivated plants. The diseased mulberry plants become weak, and the root rots. The hyphae emerging from the various fruiting bodies attack the smaller roots of the healthy plants, and spread to the main root system, causing white root rot.

Figure 9 Mulberry root with violet root rot

Violet root rot, caused by *Helicobasidium mompa,* Tanaka fungus. The First symptoms of this disease appear when mulberry does not sprout at the beginning of spring or when the leaves suddenly appear to wither in the middle of summe. The main disease characteristic is the existence of similar velvet veilings that colours the root bark dark-brown. Several reddish filamentous substances appear that colors all the root bark that are the hyphes from the pathogen.

Mulberry withering. This disease has been verified in mulberry cultivations of the state of São Paulo, mainly in the region of São José do Rio Preto. Its main characteristic is root rot. Several samples of attacked plants have been examined in research institutes and, to date, non-conclusive diagnoses are available. According to personal reports by scientific researchers, the following micro-organisms are detected in a sample from Guaraçaí, São Paulo (1997): *Fusarium* sp., *Lassiodiplodia* sp., *Fusicoccum* sp., *Meloidogyne* sp. and *Pratylenchulus* sp.

Oidium. *Phylactinia corylea* Prest Karst. Oidium is a very

common disease in mulberry plants and can cause severe damage to leaves, making them so they are unable to feed silkworm once the fungus has absorbed all the leaf nutrients. It frequently occurs in older leaves, which are covered by a greyish-white powder, made from pathogen structures. The disease is more frequent during the spring and summer, periods when favourable conditions for its development are present.

Rusty spot *Cylindrosporium mori* Targioni Tozzeti. In the beginning, the spots are small (less than 1 mm in diameter) but with the development of the process, they can reach more than 1 cm, and are brownish in colour with yellowish edges. The spots usuals to appear at the top, in the petiole and over the young branches. In severe attacks, mulberry leaves fall from the plant.

Other leaf spots caused by fungus. These attacks may be caused by fungus from the genera *Cercospora* sp., *Alternaria* sp., *Helminthosporium* sp. and *Colletotrichum* sp. Seasonally, they are more frequent during spring and summer, in periods of higher humidity and temperature.

Bacteria spots. *Bacterium mori* (Boyer & Lambert), *Bacillus curbonianus* (Macchiatti), *Bacterium moricolum* (Yendo & Higushi). Mulberry is susceptible to these kind of spots, at any age and in any aerial part of the plant. Seasonally, the disease is more frequently observed in summer (higher humidity and temperature). Initial symptoms appear as on the leaves small and sparsely distributed spots in necrosed areas, which coalesce and tear apart in a later phase, exuding yellowish pus on the lesion. The shootings can also die, causing oversprouting.

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Mulberry germplasm resources in Italy

Luciano Cappellozza
Istituto per la Zoologia Agraria

Padova, Italy

For historians, a controversy still exists regarding the origin and time of the first introduction of mulberry to Italy. Most agree that the two main species of mulberry, the Black mulberry (*Morus nigra*) and White mulberry (*M. alba*) came from Asia - the first from Persia (present-day Iran) and the second from the Far East. It seems, however, that *M. nigra* was the first to be adapted and cultivated for its fruit, not only for food but also for medicinal purposes by the Greeks and Romans. During the first century AD, Pliny highlighted its importance from the pharmaceutical and cosmetic points of view while, two centuries later, Palladio provided the earliest information on its cultivation (Bertelli Bergamaschi, 1994).

There are no precise references to the dates of the introduction and expansion of White mulberry in Europe. It is the frequent opinion of academics that the mulberry present in western Europe until mediaeval times was *M. nigra* and that *M. alba* was introduced in Italy with sericulture, and thus between the ninth and

the twelfth centuries. The first clear and unequivocal declaration of the presence of *M. alba* in Italy comes from Pescia where, in 1434 Francesco Bonvicino, upon his return from the Orient, showed some plants that he had brought back (Bertelli Bergamaschi, 1994).

The real development, in Italy and in Europe, of the mulberry cultivation with *M. alba* was determined by its link with sericulture, which made the cultivation of mulberry not only relevant, but also generalized in the territory of the Italian peninsula and in a few other European countries (Greece, France and Spain).

Both the experience gained during the course of the centuries when mulberry cultivation was practised and the most recent technical and scientific information indicate that mulberry is a rustic plant, which in Italy grows well in the flat lands, in the hills and in the mountains, up to the limit of the region of the chestnut tree. The best zones are the hills and sunny flat highlands. The best vegetative development is achieved in fertile lands with discrete water sources, but mulberry also grows well in calcaric

soils with good water availability. The plant prefers the temperate climate to colder areas, but it can be cultivated in hot regions next to the sea or the mountains which have a mitigating effect on the high temperatures. This is why mulberry plantations should be in well-exposed land.

Despite the close interdependency with silkworm, mulberry has never received much scientific interest in Italy. It has been recently written: "... it is regrettable that about a plant which has for long, long time determined the Italian agricultural landscape there is still not a systematic study which follows its evolution in time" (Zanier, 1998).

The mulberry currently cultivated for its leaves to feed the *Bombyx mori*, is mostly *M. alba*, with its various varieties and spontaneous hybrids. Some of these have been present in the territory for a long time, while others were more recently (from the 1930s to 1950s) imported from the Far East (Japan in particular). From specialized mulberry cultivation (formed basically by selected varieties), plants were disseminated throughout the

various regions of Italy, but the only remnants of previous sericultural activity are high trunk plants, isolated or aligned along fences and roads. These are either definitely "wild" plants, thus derived from spontaneous hybridization, or selected *M. alba* varieties reproduced by stakes. Often the same varieties are called differently with local names, which does not help taxonomic classification and adds to the lack of homogeneity in the systematic classification at international level. For example, varieties of *M. multicaulis* (Rangaswami *et al*., 1976), such as the Kokuso 20, 21 and 70, are described as *M. latifolia* by other authors (Machii, Koyana and Yamanouchi, 1999).

In Italy, the most important germplasm collection of the *Morus* genus is at the Sericulture Section of the Livestock Experimental Institute, Padova (Sezione Specializzata per la Bachicoltura de Padova, Istituto).

TABLE 1

List of Morus varieties in the Padova collection.

NO	species	Variety	NO	species	Variety
1	*M. multicaulis*	Lhou	2	*M. bombycis* (K)	Akagi
3	*M. alba* (L.)	Arancina	4	*M. alba* (L.)	Ascolana
5	*M. alba* (L.)	Cattaneo	6	*M. alba* (L.)	Cattaneo
7	*M. latifolia* (Poir) (*multicaulis*)	Daikokusou	8	*M. bombycis* (Koidz)	Dateakagi
9	*M. bombycis* (Koidz.)	Enshuutakasuke	10	*M. latifolia* (Poir) (*multicaulis*)	Filippine
11	*M. alba* (L.)	Florio	12	*M. alba* (L.)	Giazzola
13	*M. latifolia* (Poir) (*multicaulis*)	Goshoerami	14	*M. alba* (L.)	Ichinose
15	*M. alba* (L.)	Indiana	16	*M. alba* (L.)	Kayriou

	o *indica* (L.)?				nezumigaeshi
17	*M. latifolia* (Poir) (*multicaulis*)	Kayriou rosou	18	*M. alba* (L.)	Kayriou wase juumonji
19	*M. latifolia* (Poir) (*multicaulis*)	Kasuga	20	*M. bombycis* (K)	Kenmochi
21	*M. latifolia* (Poir) (*multicaulis*)	Kokka (?)	22	*M. latifolia* (Poir) (*multicaulis*)	Kokuso 20
23	*M. latifolia* (Poir) (*multicaulis*)	Kokuso 21	24	*M. alba* (L.)	Kokuso 27
25	*M. latifolia* (Poir) (*multicaulis*)	Kokuso 70	26	*M. latifolia* (Poir) (*multicaulis*)	Kokuso rosso
27	?	Korinne	28	*M. alba* (L.)	Limoncina

29	?	Miura	30	*M. alba* (L.)	Morettiana
31	?	Muki	32	*M. alba* (L.)	Nervosa
33	*M. nigra*		34	*M. latifolia* (Poir) (*multicaulis*)	Okaraguwa
35	*M. alba* (L.)	Pendula	36	*M. kagayamae* (K)	Platanoide
37	*M. alba* (L.)	Pyramidalis	38	*M. alba* (L.)	Restelli
39	M. *alba* (L.)	Rosa di lombardia	40	*M. latifolia* (Poir) (*multicaulis*)	Rosou
41	*M. latifolia* (Poir) (*multicaulis*)	Seijuurou	42	*M. alba* (L.)	Selvatica a lamina intera
43	*M. alba* (L.)	Selvatica a lamina lobata	44	*?*	Selvatico
45	*M. bombycis*	Shimanouchi	46	*M. alba* (L.)	Sinuense

45	*M. bombycis* (Koidz.)	Shimanoudchi	46	*M. alba* (L.)	Sindense
47	*M. alba* (L.)	Spagna a frutto bianco	48	*M. alba* (L.)	Spagna a frutto nero
49	*M. alba* (L.)	Sterile	50	*M. alba* (L.)	Tagowase
51	*M. latifolia* (Poir) (*multicaulis*)	Tougounishiki	52	*M. bombycis* (Koidz.)	Yamanaka-Takasuke

Sperimentale per la Zoologia Agraria) of the Ministry for Agrarian and Forestry Policies (MAFP). It includes varieties acclimatized for long time in Italy and those imported in the 1930s and 1950s. The Table contains a detailed list of these varieties.

Recently within the project "New technologies for the relaunching of Italian sericulture", financed by MAFP, some of these varieties are being studied phenotypically, genetically (using the RAPD technique) and for their productive and quality profile, with leaf analysis during various times of the year and different

environments (north and south of Italy). The results of this research will be published soon.

In addition, the Sericulture Section of Padova, in collaboration with the Department of Animal Biology and Genetics of the University of Florence and other research units, is preparing a project on the "multiuse of mulberry", in order to examine the possibilities of other uses of the plant besides sericulture, such as for animal husbandry, for wood, for fruit, for the food and pharmaceutical industries, for landscaping and reforestation. Within the scope of this project, will be a systematic work on germplasm collection from the wild types in the various Italian regions, on genetic analysis and on multiplication of superior genotypes. This work will start as soon as funding is assured.

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Agronomic studies with mulberry in Cuba

G. Martín, F. Reyes, I. Hernández, and M. Milera
Estación Experimental de Pastos y Forrajes "Indio Hatuey", Matanzas, Cuba;
F. García and T. González, Centro Politécnico "Villena Revolución", Havana, Cuba

INTRODUCTION

Mulberry (*M. alba*) is a shrub that has traditionally been used for feeding the silkworm. It belongs the order of Urticales, to the Moraceae family and to the genus *Morus*, with more than 30 species and 300 varieties. It derives from China and other species originate in other temperate countries. However, they can be considered "cosmopolitan" for their capacity of adaptation to different climates and altitudes. In Cuba, according to Paretas *et al*. (1997), mulberry was planted in the 1940s for sericulture purposes and flourished in various regions.

The foliage has a high nutritional value, since it contains high

levels of protein and digestibility. Mulberry does not tolerate badly drained or compacted soils, and it requires fertilization since it extracts large quantities of soil nutrients (it can use up to 50 percent of the fertilizers applied). Nevertheless, it has been shown that mulberry responds well to organic fertilizers, and yields of up to 50 tonnes/ha of edible fresh forage have been obtained with goat manure applications.

Benavides, Lachaux and Fuentes (1994) evaluated the effects of applying goat manure in the soil and the cutting frequency on biomass quality and yield in the humid tropics of Costa Rica. Three levels of goat manure (240, 360 and 480 kg of N/ha/year), two controls (no fertilization and 480 kg of N/ha/year of NH_4NO_3), and three cutting frequencies (60, 90 and 120 days) were used. The largest total DM production was with the cutting frequency of 120 days, although there was no difference in edible biomass between 90 and 120 days. Manure levels proportionally increased total and edible biomass yield, and the highest level of manure application (equivalent to 480 kg of N/ha/year) significantly exceeded both controls.

In the dry tropics of Guatemala, Rodríguez, Arias and Quiñones (1994) found that biomass production increased with shorter cutting frequencies (six, nine and 12 weeks) and higher fertilizer doses (40 and 80 kg of N/ha/year as urea). There was a positive interaction between both factors.

There are many aspects of this plant still to be studied, particularly in Cuba, particularly because of the need to find new forages of higher nutritional value than the conventional ones. The studies should be directed towards the different production systems and ecological conditions.

The objective of this paper is to present the results of the various agronomic studies carried out in Cuba with *M. alba*.

METHODOLOGY

Experiment 1

At the Indio Hatuey Grass and Forage Experimental Station

(EEPF Indio Hatuey, 22°48'7" north and 81°2' west, at 19 m above sea level), an experiment was conducted in a plantation of "Tigreada" variety with a complete random design. Two cutting heights (50 and 100 cm) and three cutting frequencies (45, 60 and 90 days) were used. Each treatment was represented by 20 plants randomly distributed in the field. They were planted at a spacing of 1 m between lines and 0.40 m between plants. They were not irrigated and poultry manure was applied twice at the rate of 150 kg N/ha/year during the rainy season.

In one year eight, six and four cuts were given at the frequencies of 45, 60 and 90 days, respectively. In 20 plants from each treatment total biomass and its components (leaf, woody stem and young stem) were determined, and the edible biomass calculated. Total biomass yield per ha was calculated from the mean dry weight of individual plants and a density of 25 000 plants/ha. For data processing, descriptive statistics and analysis of variance were used.

Experiments 2 and 3

At the Centro Politécnico "Villena Revolución", with typical red ferralitic soils, two experiments were conducted to study cutting height and frequency on biomass yield and on quality during the dry period of October 1998 to April 1999. The two experiments were set in a 1.5 ha area, using a random block design with four repetitions.

The experimental plot was composed of ten plants, with eight plants used as net plot. In total there were 32 plants per treatment. Total biomass and the three fractions were determined in each plant, and a plot sample was taken for N and fibre analysis. Cutting heights and frequencies were 20, 30 and 40 cm, and 45, 60 and 90 days, respectively. In experiment 2 the cutting frequency was 90 days and cutting height 30 cm.

Experiment 4

This study was carried out at Indio Hatuey Station in a well drained red-ferralitic soil. There were four treatments: a) mulberry; b) mulberry + 50 kg of N; c) mulberry + dolicho (*Lablab*

purpureus); and d) mulberry + canavalia (*Canavalia ensiformis*). A random block design with four repetitions was used. Plot size was 10 x 10 m. The "Tigreada" variety was planted in September 1998, at 1 x 0.4 m spacing with 40 cm stakes. The two legumes were planted next between mulberry lines. These legumes were harvested when pods turned from green to yellow (06/01/99 for dolicho and 05/04/99 for canavalia). Nitrogen fertilizer was applied 60 days after planting.

Two manual weedings were done and mulberry was first harvested at one year of age. Parameters measured were total biomass yield (TDMY), edible biomass (EDMY), height, branch number, legume grain yield and legume plant yield. The Duncan (1955) test was used to interpret the results.

RESULTS AND DISCUSSION

Experiment 1

The analysis of total biomass yield showed highly significant

differences (P<0.01) among cutting frequencies. Cutting height and the interaction height x frequency were non-significant.

The 90 days frequency gave the highest yield (1 031 g DM/plant/year). This result infers that 25 tonnes of DM can be produced per ha per year (with 25 000 plants/ha). Edible biomass production showed similar results. At the 90 days frequency 645 g of edible DM were produced per plant, equivalent to 16 tonnes/ha/year or 63 percent of total biomass. The 45 and 60 day frequencies yielded less edible biomass despite the higher edible fractions in the total DM yield.

TABLE 1

Effect of cutting height and frequency on biomass yield (g DM/plant/year).

Variable	Cutting height (cm)			Cutting frequency (days)			
	50	100	SE±	45	60	90	SE±

Total biomass	650	670	44	537[b]	514[b]	1 031[a]	62 ***
Edible biomass	533	453	85	456[b]	378[b]	645[a]	120 *
Edible biomass (%)	82	68		85	74	63	

[a b] Significantly different, horizontally P <0.05; * P < 0.05; *** P < 0.001

These results are similar to those obtained in the humid tropics of Costa Rica by Benavides, Lauchaux and Fuentes (1994) and in the dry tropics of Guatemala by Rodriguez, Arias and Quiñones (1994).

The biomass proportions (Figure 1) more clearly show the influence of cutting frequency. On the contrary, cutting height had no effect. Proportions of leaf and young stems go down as cutting intervals increase, but the woody stem fraction goes up. These results are closely linked to the growth process, by which

sclerenchymatous tissues increase proportionally with age.

Experiment 2

Cutting height did not have an effect on total and fractional biomass yields during the dry period of 1998-99 (Figure 2). Nevertheless, according to studies from other countries (Benavides, 1986), cutting height has not shown a clear tendency in its effect on biomass yield.

It should be noted that among plant fractions, the leaves gave the highest yield with approximately 55 percent of total biomass. Adding the young stem fraction of 12 percent, it can be inferred that over 60 percent of total biomass is edible. This means that over 7 tonnes of DM/ha were obtained during the dry period, a result superior to those of other conventional forages obtained under these experimental conditions.

There were no differences in protein and fibre due to cutting height (Table 2). Protein was obviously higher and fibre lower in

leaf and edible stems.

TABLE 2

Effect of cutting height on protein and crude fibre of total biomass and fractions

Variables	Crude protein (%)			Crude fibre (%)		
	Height (cm)			Height (cm)		
	20	30	40	20	30	40
Total biomass	16.1	16.0	14.7	29.6	27.9	23.8
Leaf	21.0	21.6	21.6	16.1	17.8	15.1
Edible stem	8.7	8.6	8.9	41.8	38.8	39.3
Non-edible stem	5.4	4.9	5.3	47.3	44.1	50.7

Experiment 3

There were significant differences ($P < 0.05$) on the effects of

cutting frequency on total and fractional biomass yields (Table 3). All yields increased with cutting interval, with the greatest values at 90 days.

Table 4 indicates that the percentage of leaf and edible biomass decreased as cutting interval increased, whereas woody stem showed the reverse effect.

TABLE 3

Effect of cutting frequency on total and fractional biomass production (tonnes de MS/ha) during the dry period 1998-99

Variables	Cutting frequency (days)				
	45	60	75	90	SE
Non-edible stem	0.06^{c}	0.38^{c}	1.15^{b}	3.38^{a}	0.263 *
Edible stem	0.33^{b}	0.41^{b}	0.82^{a}	0.83^{a}	0.087 *
Leaf	2.70^{c}	2.60^{c}	3.79^{b}	5.24^{a}	0,261 *

Total biomass	3.09^{c}	3.39^{c}	5.76^{b}	9.45^{a}	0.493 *

a, b, c Significantly differ horizontally P <0.05; *P <0,05;

TABLE 4

Effect of cutting frequency on the percentages of biomass components

Variables	**Cutting frequency (days)**			
	45	**60**	**75**	**90**
Leaf	87.4	76.7	65.8	55.4
Edible stem	10.6	12.1	14.2	8.8
Non-edible stem	2.0	11.2	20.0	35.8
Edible biomass	98.0	88.8	80.0	64.2

The results obtained in this experiment with the 90 days cutting frequency are similar to those obtained in experiment 2, demonstrating the great potential of mulberry to produce biomass during the dry period.

There were significant differences ($P < 0.05$) in protein content of various fractions with cutting frequency (Table 5). Protein decreased with longer cutting intervals, indicating greater lignification and more fibre (Table 6). This tendency was not observed in the edible stems, although at 90 days the protein content was the smallest.

Considering that DM production reaches 9.5 tonnes/ha during the dry period, with 15.6 percent CP, it is possible to produce 1.5 tonnes of CP/ha, which is equivalent to the yield of transgenic soybean in one year (Preston, 1999). This means that mulberry can produce three times more protein than transgenic soybean in a year.

TABLE 5

Effect of cutting frequency on protein content

Variables	Cutting frequency (days)				
	45	60	75	90	ES
Total biomass	24.1[a]	16.0[b]	14.7[c]	15.6[bc]	8.38 *
Leaf	27.0[a]	24.4[b]	23.6[b]	21.4[c]	0.36 *
Edible stem	11.5[a]	10.8[a]	11.2[a]	8.9[b]	0.42 *
Non-edible stem	-	11.8[a]	9.2[b]	7.6[c]	0.04 *

[a,b,c] Significantly different horizontally; * P <0,05

TABLE 6

Effect of cutting frequency on crude fibre percentage

Variables	Cutting frequency (days)				
	45	60	75	90	SE

Total biomass	26.5	25.2	25.0	30.0	1.29^{NS}
Leaf	14.0^{b}	12.4^{a}	15.5	15.1	0.47^{*}
Edible stem	41.2	39.7	38.6	40.6	1.25^{NS}
Non-edible stem	40.5	40.0	37.2	44.0	0.70^{NS}

a, b NS Non-significant

Experiment 4

Table 7 shows total and edible production. There were no significant differences among treatments A, B and C, although B had the largest total yield (9.8 tonnes/ha). The lowest production of edible (2.5 tonnes/ha) and total biomass (5.3 tonnes/ha) occurred with canavalia (D), which was significantly ($P < 0.01$) lower than the other treatments. This could be due to the very aggressive growth of canavalia, which covered mulberry branches intercepting light. Cover crops if not managed adequately can

become weeds, shading the main crop and competing with water and nutrients (López and Hernández, 1997). This can be resolved with various management practices such as pruning, and spatial orientation.

TABLE 7

Effect of intercalated legumes on mulberry yield

Treatment	EDMY	TDMY
Mulberry alone	3.4[a]	8.5[a]
Mulberry + 50 kg of N	3.8[a]	9.8[a]
Mulberry + dolicho	3.5[a]	9.4[a]
Mulberry + canavalia	2.5[b]	5.3[b]
SE ±	1.8***	3.30***

EDMY = Edible DM yield; TDMY = Total DM yield [a,b]
Significantly different vertically; *** P <0.001.

Plant height and branch number are presented in Table 8, without any differences due to treatments.

TABLE 8

Effect of intercalated legumes on height and branch number at first cut.

Treatment	Height (cm)	Branch number
Mulberry alone	3.75	3.1
Mulberry + 50 kg of N	2.70	2.8
Mulberry + Dolicho	3.10	2.9
Mulberry + Canavalia	2.77	2.9
SE ±	0.16 NS	0.11 NS

NS Non-significant.

The results in DM production during the establishment period

coincide with those of Martín *et al*. (1998) for this same variety.

Intercalated legumes (Figure 3) produced additional grains: 0.87 t/ha for dolicho and 0.92 t/ha for canavalia, plus crop residues, which can help in maintaining soil fertility through nutrient recycling.

Figure 1. Mulberry biomass fractions (%) by cutting frequency and height

Figure 2 Influence of cutting height on yields of total biomass, leaf, edible stem (dry period)

Figure 3 Seed and crop residue yield of intercalated legumes with mulberry

This trial showed that it is possible to substitute certain quantities of nutrients that mulberry requires by intersowing short-cycle herbaceous legumes. Although there were no significant differences among treatments [a], [b] and [c], treatments [b] and [c] had

1.3 and 0,9 tonnes/ha more biomass yield compared to a. In addition, treatment ^{c} additionally had 870 kg/ha of legume grain and 350 kg of crop residue. These were later incorporated with the soil, but could be used as feed. All this indicates that studies should continue to determine more accurately the effects of intercalating short-cycle legumes on the biological, economic and ecological sustainability of mulberry under cut-and-carry systems.

FINAL CONSIDERATIONS

As part of the research programme being carried out in Cuba with *M. alba*, the four agronomic experiments concluded to date have been included in this article. From these the following was observed:

- In experiments 1 and 2 it was determined that cutting heights (20, 30, 40, 50 and 100 cm) did not significantly influence DM production (total and fractional) or protein and crude fibre contents.

- Cutting frequencies in experiments 1 and 3 (45, 60, 75 and 90 days) significantly affected total and fractional biomass yield and protein and fibre contents. In both trials, the 90 day frequency gave the best results.

- Intercalated legumes can contribute to improving biological, economic and ecological sustainability of mulberry.

- Yield and quality results of these mulberry studies, in particular during the dry period, demonstrate the potential of this plant for Cuban conditions. This justifies further agronomic studies for introducing mulberry to livestock farms in the country.

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Establishment and management of mulberry for intensive forage production

Carlos F. Boschini

Experimental Station Alfredo Volio Mata
University of Costa Rica
Tres Ríos, Costa Rica

INTRODUCTION

Mulberry, originated from temperate zones in Asia, has now spread throughout the world (Benavides, Lachanx and Fuentes, 1994). In tropical Central and South America, it has adapted excellently (Rodríguez, Arias and Quiñones, 1994). It is a perennial tree or shrub that is easily propagated, with fast growth and vigorous shooting. It develops a strong vertical and profuse horizontal root system (Paolieri, 1970). These features improve physical soil conditions and allow better water conservation. As forage, mulberry has shown excellent organoleptic intake for livestock (Benavides, Lachanx and Fuentes, 1994; Ortiz, 1992; Castro, 1989).

Protein content varies from 14 to 22 percent on a dry matter (DM) basis (Piccioni, 1970) and *in vitro* digestibility between 70

and 80 percent (Ortiz, 1992).

Under tropical conditions, where conditions favour plant growth, mulberry culture has been practised under various densities and cutting frequencies, which result in large yield differences. In Guatemala, Blanco (1992) obtained 19 tonnes of DM/ha in four cuts every nine weeks, with 30 cm between plants and a cutting height of 75 cm. In Costa Rica, Benavides, Lachanx and Fuentes (1994) used densities of almost 23 000 plants per ha, with DM yields from 21 to 28 tonnes/ha. Rodríguez, Arias and Quiñones (1994) worked in Guatemala with planting distances of 60 and 80 cm between plants and harvesting frequencies of six, nine and 12 weeks, with DM yields of 1 to 4.6 tonnes/ha/harvest. These results suggest that yield increases with density (Benavides, Borel and Esnaola, 1986).

In Japan two planting densities are used, 10 000 and 20 000 plants/ha for the traditional and intensive production systems, respectively (IFA, 1992).

This paper presents the experimental results of the effects of planting densities, cutting heights and frequencies of harvest on DM production in a high altitude tropical environment.

ENVIRONMENTAL CONDITIONS AND ESTABLISHMENT

The study was conducted at the Dairy Cattle Experimental Station "Alfredo Volio Mata" at the University of Costa Rica, located at 1 542 m above sea level, with 2 050 mm of annual rainfall (May to November), mean temperature of 19.5ºC and relative humidity of 84 percent. The soil is volcanic, classified as typic distrandepts (Vásquez, 1982), with medium depth, good drainage and medium fertility (Ca 7.7; Mg 3.0; and K 1.54 cmol/l; P 10.0; Cu 28.8; Fe 234; Mn 6.3; Zn 2.6 mg/l). The pH is 5.9. The zone is considered a Low Mountain Humid Forest (Tosi, 1970, cited by Vásquez, 1982).

The mulberry plantation was established with young stakes of 1-2 cm in diameter, 40 cm in length and with at least three buds, at 5-8 cm in depth at three planting densities: 60, 90 and 120 cm

between rows and plants, equivalent to 27 777, 12 345 and 6 944 plants/ha. It was fertilised with a 10-30-10 formula at the rate of 120 kg of P205/ha/year. In July and October ammonium nitrate was applied in two equal doses to complete 150 kg of N/ha/year. After one year, half of the plot was cut at 30 cm in height and the other half at 60 cm. From that time, cuts were made every 56 days (six cuts); 84 days (four cuts) and 112 days (three cuts) for 336 days.

Weeding was done after each harvest, leaving cut weeds between rows. Ammonium nitrate was applied when the shoot reached 3-5 cm (approximately two weeks post-harvest) at the rate of 300 kg N/ha/year (Rodríguez Arias and Quiñones, 1994).

Leaf and stem samples were dried at 60^{o}C for 48 hours, and after grinding DM determinations were made at 105^{o}C.

FORAGE PRODUCTION

The Table presents DM yields by density, height and cutting

frequency (P = 0.0l). Density strongly influenced yields. Yields dropped 37 percent (10.2 tonnes/ha) from planting densities 60 to 90 cm and 13 percent (2.2 tonnes/ha) from 90 to 120 cm. Leaf:stem proportion did not change among planting densities despite yield differences. More DM was produced at the 60 cm cutting height (P < 0.01) because more leaves.

TABLE 1

Annual dry matter production (tonnes/ha) of mulberry depending on planting density, cutting height and frequency

	Cutting		Fraction			Leaf:
Spacing (cm)	height (cm)	Frequency (days)	whole plant	Stems	Leaves	stem ratio
60	30	56	18.3	7.1	11.2	1.60
60	30	84	25.1	11.4	13.7	1.20
60	30	112	40.6	21.6	19.0	0.88
60	60	56	24.4	9.2	15.3	1.75

60	60	84	35.8	16.3	19.5	1.19
60	60	112	30.9	15.8	15.1	0.94
90	30	56	10.2	4.0	6.2	1.63
90	30	84	16.5	7.8	8.6	1.11
90	30	112	26.8	14.5	12.3	0.85
90	60	56	11.2	4.5	7.3	1.64
90	60	84	21.5	9.3	12.2	1.32
90	60	112	20.8	10.3	10.4	1.04
120	30	56	10.0	4.2	5.9	1.40
120	30	84	15.5	7.5	8.0	1.08
120	30	112	19.2	10.4	8.8	0.86
120	60	56	10.1	39.7	60.8	1.63
120	60	84	15.8	7.2	8.6	1.22
120	60	112	20.9	10.9	10.0	0.96
Means						

60			27.5	12.3	15.1	1.36
90			16.3	7.5	9.0	1.35
120			14.1	6.6	7.5	1.27
	30		18.4	8.7	9.8	1.26
	60		20.1	8.9	11.3	1.38
		56	14.0	5.5	8.7	1.61
		84	21.7	9.9	11.8	1.19
		112	26.5	13.9	12.6	0.93

Total and stem DM yields increased linearly ($P < 0.01$) with the length between harvests, but leaf yield only increased from 56 to 84 days. Leaf proportion decreased linearly with harvest length. Up to 100 days there were more leaves than stems. Leaf production is little affected by cutting frequency. The interaction planting density by cutting height was significant for the whole biomass and highly significant for leaf yield. Density by frequency interaction was not significant for whole plant, leaf and leaf:stem ratio, but highly significant for stem yield.

Height by frequency interaction was significant ($P < 0.01$) for all DM yields but not for leaf:stem ratio, despite the wide range (0.96 to 1.68) observed. At 30 cm of cutting height DM increases with cutting length, but at 60 cm height, DM yields do not raise further 84 days. Similar effects are seen with leaf and stem yields.

The three-way interaction - height, frequency and density - was significant for the three variables measured, but not for leaf:stem ratio.

DISCUSSION

Forage mulberry plantations had been studied for the humid tropics in Costa Rica (Benavides, Lachaux and Fuentes 1994) and for the dry tropics in Guatemala (Rodríguez, Arias and Quiñones, 1994). The present study was conducted in a high environment (1 542m) with excellent solar radiation throughout the year. Annual DM yields differed greatly depending on density, cutting frequency and height, which should be considered during

establishment and management. Planting distance was responsible for 39.5 percent of total variation in DM yields, cutting height only 0.80 percent and frequency 30.64 percent.

Individual plant DM yields were 0.99, 1.31 and 2.03 kg/year for planting distances of 120, 90 and 60 cm, respectively. In China, traditional density is 10.000 plants/ha (IFA, 1992; FAO, 1988) and 25 000 for intensive cultivation. Lin, (1996), Yu and Hsieh (1994), studied spacing effect (1.5 x 0.6, 1.8 x 0.60, 1.5 x 0.75, 2.25 x 0.60, 1.80 x 0.75 and 1.8 x 0.9 m) on leaf production, and found similar results to those of the four times per year harvest of the present experiment. Higher shooting per plant does not compensate for higher shooting per hectare at higher densities. In general terms, larger spacing reduces light competition (González, 1951) and high-density plantations respond to this competition. The long-term effects on the root system and leaf yield are unknown.

Cutting height had a little effect on yield, increasing by 1.7 tonnes DM/ha/year from 30 to 60 cm. Both of these heights are

considered low for Chinese practices (FAO, 1988). This increment was due to the leaf fraction. In Turrialba (Costa Rica) annual plant yields were 2.32 kg cutting at 50 cm and 2.12 kg at 100 cm in low-density plantations (Benavides et al, 1986). Some reports recommend low cutting heights (< 70 cm) for 30 000 plants/ha; medium height (70-170 cm) for 12 000 plants/ha and high cutting (> 170 cm) for densities below 6 000 plants/ha (FAO, 1988). Greater leaf production at 60 cm suggests that leaf and stem yields should be studied at various cutting heights under high light competition in dense plantations.

Frequency of defoliation had a marked effect on yield. Greater yields were observed at longer cutting frequencies. This is related to the regrowth delay period and to plant nutrient reserves. The results clearly show that annual production is lower at short intervals. Similar responses were obtained by Rodríguez, Arias and Quiñones (1994) when studying frequencies of harvesting of six, nine and 12 weeds in two different periods in Guatemala. In the second year the yield was triple but the frequency effect was maintained. When studying plant growth post-harvest, it was

observed that stem buds do not regrowth immediately. It takes four to ten days for the shoot to reach 1 cm. Afterwards, the re-growth continues with two to three buds on side branches. The density of re-growth seems proportional to the number of cuts. These observations indicate that plant structure and morphology, reflected on leaf and stem proportion, change with cutting frequency. After each harvest there was a little flux of sap in each cut. The results of this experiment show that plant stress (Taiz and Zeiger, 1991), caused by cutting frequency has, in the short term, a negative effect on annual biomass yield.

In Asian countries, often leaves are only picked every two to three months, and there is an annual pruning. In more intensive systems, leaf harvest/high pruning in the spring is combined with leaf harvest/low pruning in the winter (FAO, 1988).

IMPLICATIONS AND RECOMMENDATIONS

Annual biomass yield increased with planting density. This implied lower individual plant yield, indicating competition for basic ground

space (root growth and nutrition) and aerial space (gaseous exchange and photosynthesis). Cutting height had little effect on biomass production. This should be considered for mechanical harvesting.

Biomass, stem and leaf yield rose with longer cutting intervals. With frequent harvests, forage had a larger leaf proportion. Leaf:stem ratio reached 1 at about 100 days, then forage became lignified, losing nutritive value.

This study found the largest leaf production (19.0 tonnes) at 60 cm spacing and 112 days cutting frequency. Similar spacing is recommended for an 84 days interval, with only slightly less leaf (-0.5 tonnes) and stem (-5 tonnes) production, with cutting height of 60 cm and leaf:stem ratio of 1.19. With a cutting height of 30 cm, 112 days frequency and 60 cm spacing, the total yield reached 40 tonnes/ha/year, but leaf yield was 18.7 tonnes/ha/year. Forage with more leaves saves on labour and transport cost per unit of feed, and animals can derive a greater intake.

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