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GENETIC DIVERSITY AND SUITABILITY OF MULBERRY (*MORUS* SP.) FOR CULTIVATION IN ARID ECOLOGY

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INTRODUCTION

India with diverse soil and climatic conditions comprised with several agro-ecosystems, provides a huge opportunity to cultivate a variety of horticultural crops but an arid ecosystem is most vulnerable to climate change. In the arid ecosystem, 'Thar Desert' is the ninth largest desert of the world, but it has abundant biodiversity status. The vegetation of this region is adapted to xerophytic conditions. It is a biodiversity hotspot of a huge flora and fauna which are flourishing under such a harsh conditions. The adapted species of hot arid zone have specific traits of high significance in future for climatic changes and/or the emergence of new diseases (Saroj *et al.* 2020). On the other hand, herbal nutraceuticals and antioxidants are gaining momentum world over for human being as well as animal's health care and arid flora are treasure house of such traits. Mining of unique genes from arid flora provides ample scope for imparting abiotic stress tolerance in the high yielding commercial crop cultivars (Saroj *et al.* 2020). Most of the native flora of this region is unexploited and underutilized which require sincere research efforts for their conservation and sustainable utilization at commercial level. Mulberry (*Morus spp*.) is one of these crops which is widely distributed in the temperate, subtropical, or tropical regions of the world and can grow in a wide range of climatic, topographical, and soil conditions (Hosseini *et al.*, 2018).

Mulberry domestication was started several thousand years ago because of requirement for silk worm rearing. Mulberry is common all over India. *M. laevigata* is an important timber species of north-east and Western Ghats. Its large scale cultivation is being done in Andhra Pradesh, Karnataka, West Bengal, Tamil Nadu, Uttar Pradesh, Assam, Manipur etc. Although, the maximum utilization of mulberry is in Asia, it does not mean that cultivation is limited only to Asian countries. Mulberry is present in almost all continents of the world and is being used for several purposes, including ornamentals, in gardening and landscaping (Vijyan *et al.* 2012; Kumar and Haldhar, 2021). Mulberry foliage is the only food for the silkworm (*Bombyx mori*) and 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 (Baidya and Chatterjee, 2020). 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 over 242 thousand hectares (https://www.statista.com). However, its cultivation for fruit production is very low, despite its nutritive and functional food importance.

In traditional Indian Ayurvedic and Chinese herbal medicine, mulberry fruits and leaves have been used in folk medicine to treat diabetes, hypertension, anemia, and arthritis. Anthocyanins are the most important constituent of mulberry fruits, which are a group of naturally occurring phenolic compounds that are responsible for the colour attribute and biological activities such as antioxidant, antimicrobial, and neuro-protective, anti-inflammatory properties. The ripe fruit of mulberry is highly appreciated for its delicious taste which is consumed fresh or after extraction of juice from fruits. Chutney is prepared from unmature fruits. Its fruit is used to treat various human diseases such as weakness, dizziness, tinnitus, fatigue, anemia and incontinence *etc*. The ripe fruit is sweet in taste with acidic blend due to the presence of high water content and low level of other flavouring ingredients. The ripe fruits constituted 8-9 per cent sugar and 1-2 per cent acid. Mulberry is also considered as 'Kalpa Vriksha' because almost all the parts of it have economic value. Throughout the Asia, mulberry is highly appreciated for its delicious and thirst quenching fruits, which is utilized either fresh or in juice form. Sericulture industry needs mulberry foliage for the rearing of silkworm. In India, most of the states have initiatives sericulture as an important agro-industry with excellent results. By growing mulberry, a farmer obtains fodder, fuel and manure (FAO, 2016; Kumar and Haldhar,

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2021). Mulberries are fast-growing plants and most suited for sericulture related industries and also can be maintained as a bush. They yield huge amounts of renewable biomass in the form of leaves, branches, shoots and fruit. Indian farmers feed their house hold animals mulberry foliage by mixing with straw. Pruned branches of mulberry are used for fuel purpose and remaining twigs are allowed to dry in the garden and residues of silk worm rearing are converted in to manure which is used for mulberry orchards by putting them in a pit upto 4-5 months before use for proper decomposition. This crop may be better exploited as an energy crop in cultivated as well as wastelands, canal bunds, low-lying areas, roadsides and at fringe areas of the forest under several afforestation, soil conservation and watershed development programmes because mulberry orchard produces about 12.1 tonnes of mulberry sticks per hectare per year which generate (50% moisture loss) 27830 Kcal (@ 4600 calories/kg of mulberry wood) energy per hectare (FAO, 2016).

Looking into these aspects preliminary studies on the feasibility of mulberry fruit production in arid climate, fifteen genotypes were collected from different parts of the country including two genotypes from NBPGR, New Delhi. Out of that, fifty clonal plants each of three genotypes viz., CIAH Selection 1, 2 and Gurgaon Local were planted in 2007 and evaluated for several morphological and yield parameters. CIAH Selection 1 (Purple red colour) and CIAH Sel. 2 (Greenish white) was found superior to Gurgaon Local (Greenish white) and identified as Thar Lohit and Thar Harit at institute level, respectively. A wide range in term of fruit length (0.9 cm to 9.4 cm) and weight (0.5 gm -7.2 gm) was recorded in different genotypes under field condition of arid ecosystem. The mulberry plants of almost all genotypes were found to tolerate extreme cold and hot temperatures of the arid region. Thus this crop can be viewed one of the sustainable fruit crops of arid region.

Origin, distribution, genetic diversity and varietal wealth of mulberry

The white mulberry is native to eastern and central China. It became naturalized in Europe centuries ago. The tree was introduced into America for silkworm culture in early colonial times and naturalized and hybridized with the native red mulberry. The red or American mulberry is native to eastern United States from Massachusetts to Kansas and down to the Gulf coast. The black mulberry is native to western Asia and has been grown for its fruits in Europe since before Roman times (*Kadam et al*, 2019). There is much diversity exists in available germplasm pool of mulberry in India and abroad. Being a perennial and out breeding tree, mulberry exhibit high degree of heterozygosis and often produces recalcitrant seed. Therefore, for conservation of mulberry outside its natural habitats, a field gene bank has been established at a Central Sericultural Germplasm Resources Centre, Hosur, Karnataka where a large number of species such as *M. alba* L., *M. indica* L., *M. teliaefolia* Makino, *M. nigra* L., M. *serrata* Roxb., *M. laevigata* Wall, *M. rubra* L., *M. austral*, *M. cathay Ana* Hems, *M. multicaulis* Poir, *M. rotundiloba* Koidz, *M. sinensis* Hort. and *M. bomycis* Koidz *etc*. are being maintained. Several cultivars of mulberries have been introduced in the country from Japan, France and Romania for evaluating climate suitability (Kumar and Haldhar, 2021). There are about 68 species of the genus *Morus* and majority of these species occur in Asia, especially in China (24 species) and Japan (19 species). 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* are domesticated and others *M. rubra*, *M. nigra*, *M. serrata* and *M. laevigata* grow wild in the Himalayas (Vijayan *et al.*, 2011).

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*. According to colour the species are White Mulberry (*Morus alba* L.), Black Mulberry (*M. nigra* L.), American Mulberry, Red Mulberry (*M. rubra* L.). There are hybrid which exist between *Morus alba* and *M. rubra* types. 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* were present (FAO, 2016). Though mulberry cultivation is practised in various climates in India, 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. Till today, selection has only been a method of crop improvement in mulberry for fruits purpose. However, hybridization has been in trend for genetic improvement in sericulture, which follows a particular procedure (Vijayan *et al.*, 2012). There are several varieties/cultivars/genotypes found growing in USA and other countries for one or other purposes tabulated under here with specific characters (Table 1).

The characterization of germplasm accessions prior to parental selection is carried out using various morphological, biochemical, physiological characters,

photosynthesis, water use efficiency, rooting ability of stem cuttings, leaf yield, leaf moisture, protein, sugar contents, etc. Parents with desired traits are selected based on a statistical assessment and control hybridization is done. No variety was developed in mulberry for commercial fruit production till date. However, promising selections viz., CIAH Mulberry Selection-1 and CIAH Mulberry Selection-2 for commercial cultivation have been identified at ICAR-CIAH, Bikaner in the name of 'Thar Lohit' and Thar Harit, respectively. Mulberry genotype Thar Lohit was found better than CIAH selection-2 in terms of antioxidant attributes such as total antioxidant activity, polyphenol, flavanol, and flavonoid (Kumar and Haldhar, 2021). One more genotype of mulberry named Delhi Collection has also been shown promising in terms of fruit length (5-9 cm), width (1-1.2 cm), weight (4-6 g), attractive reddish to maroon colour, organoleptic traits and consumers acceptability at ICAR-CIAH, Bikaner. There have been some varieties/cultivars/genotypes identified in various parts of mulberry growing institutions/ organizations in India for one or other purposes tabulated under here with their suitable region, purpose (Table 2).

Adaptation

The white mulberry and red mulberries to some extent are tolerant to drought and poor soils. Former is considered a as weed tree in various parts of the country and later one is more fastidious and faring less well in cold climates. Out of three species, the white mulberries are the most cold hardy although hardiness ranges from one type to another while black mulberry is the least cold-hardy. Some are damaged at a temperature of 25°F, while others are unfazed at -25°F temperature. Red mulberries are hardy to sub-zero temperatures (https://crfg.org/wiki/fruit/ mulberry). In general it is limited to USDA Hardiness Zone 7 (0° to 10° F average minimum) or warmer.

Botanical description

Mulberries are fast growing, deciduous, woody perennial plant having deep root system. Plants are generally dioecious. The black mulberry is the smallest over red and white mulberry and sometimes grows up to 30 feet in height, but becomes a bush if not trained at younger stage. White mulberry can grow fast, small to medium-sized tree up to a height of 10-20 metres (Kadam *et al.*, 2019) and is the most variable in its form from drooping to pyramidal shape. Red mulberry can grow up to 70 feet height in the rich soils of South Indian conditions. The white mulberry leaves are thin, glossy, light green variously lobed even on the same plant. Red mulberries leaves are larger, thicker, blunt toothed and often lobed, rough on upper surface while pubescent under side. Leaves of black mulberry are similar to red mulberry leaves but with sturdier twigs and fatter buds. Mulberries are either dioecious or monoecious and sometimes change their form from one sex to another. The flowers are held on short, green, pendulous structure of inflorescence called catkin with drooping peduncle bearing unisexual flowers. Male catkin is somewhat longer than the female one. Catkins come in the leaf axils of the current season's growth and also on spurs of older wood. Catkins are wind pollinated and sometimes set fruit without any pollination. In Californian agro-climatic conditions mulberries set fruit without any pollination mechanism. The ovary is uni-celled having bifid stigma. Mulberry fruit is called as sorosis and mainly violet black in colour. Most of the cultivated varieties of the *Morus* species are diploid with 28 chromosome number. However, triploid {2n=(3x)=42} mulberries are also in cultivation for their specific characteristics such as adaptability in various conditions, vigorous growth habit and good quality leaves for sericulture industry. Natural polypoids are common in mulberry, though diploids are more frequent. Tetraploidy with 56 chromosomes ($2n = 4x = 56$), hexaploidy with 84 chromosomes ($2n = 6x = 84$) and octaploidy with 112 chromosomes ($2n = 8x = 112$) forms are also found in nature. Mulberry chromosomes length are reported small which varies from 1.17 μm to 5.23 μm (Vijayan *et al.*, 2012).

Edapho-climatic requirements of mulberry

Mulberry thrives well in various edapho-climatic conditions and found growing from subtropical to tropical and temperate regions of the world located north of the equator between 28° N and 55°N latitude. It can be cultivated up to an elevation of 1000 metre above sea level. Mulberries like well-drained soil, preferably a deep loamy soil. However, studies at ICAR-CIAH, Bikaner reported that it can also be grown well in sandy soils with proper filling of pits with organic manure and clay soil during planting time. It requires 6.5 to 6.8 optimum soil pH although cultivation can be done with soil pH from 6.2 to 6.8. Amendments can be used to correct the soil for desired pH. It can grow well where annual rainfall varying from 600 to 2 500 mm with optimum temperature and humidity ranges from 24 to 28°C and 65-80%, respectively. However, in low rainfall areas, mulberry growth is limited due to moisture stress resulting in poor yields. It can also grow and thrive well under hot

arid conditions and some genotypes/ cultivars (Thar Lohit, Thar Harit) can thrive and give good yield (fruits) even above a temperature of 40 °C. Thar Lohit can tolerate temperature from as low as 3°C and as high as 48°C under arid conditions (Kumar and Haldhar, 2021).

Plant Propagation

Mulberries are mostly propagated through budding although they can be propagated through seeds also. Seed propagated plantation bears fruits after 8-10 years which is not desired in today's context. Seeds are sown immediate after extracted from the fruit, although white mulberry seeds germinate better after one to three months before planting with stratification. For budding, a T-cut shape is made in the rootstock and a smooth cut made on the lower side of the scion. The scion is then inserted into the T and wrapped and sealed. Other types of grafts are also usually successful, although there may be incompatibility between white and black mulberries. The stem cutting is the most common method of propagation due to the distinct advantages like speedy multiplication and maintenance of the desired characters. Hardwood, softwood and apical shoot are suitable methods for propagating mulberries. White mulberries can be multiplied through softwood cuttings which root easily when treated with rooting hormone. Red mulberry is difficult to root and also black mulberry is somewhat difficult to root because of much bleeding from cut ends. The mature shoots of 6-8 month age with 15-20 cm length, 10-12 mm in diameter, 3-4 healthy buds are selected for the purpose. Cuttings should be made at an angle of 45° with a sharp knife without bark split. Cuttings are potted in sand beds or pots during winter which start sprouting with increase in temperature during spring season which can be shifted to polythene/ earthen pots for growth (Kumar and Haldhar, 2021; https://crfg.org/wiki/fruit/mulberry).

Table 1. Mulberry varieties being in abroad with peculiar features

Variety/genotype	Species	Character	Special feature	Source/origin
Black Persian	*Morus nigra*	Fruit large, black and juicy	Fairly drought-resistant	Selection
Collier	*M. alba* x *M. rubra*	Fruit medium, purplish-black, sweet flavour	Relatively drought hardy	Hybridization
Downing	*M. alba* var. *multicaulis*	Fruit black with excellent flavour	Ripens from June to September	Selection from seed sown about 1846
Illinois Everbearing	*M. alba* x *M. rubra*	Fruit black, nearly seedless, large and very long, very sweet with good flavour	Vigorous and somewhat dwarf, extremely hardy	Originated in White County, Illinois
Kaester	*M. nigra*	Fruit large, elongated, black or deep purple, very sweet flavour	Tree bears heavily	Originated in Los Angeles
Pakistani	--	Fruits very large, ruby-red, sweet, flesh firmer than most of other named cultivars	Tree spreading with large heart-shaped leaves, recommended for the deep South and mild winter areas	Originated in Islamabad, Pakistan
Riviera	--	Fruits elongated, deep purple-black, slightly juicy, very sweet	Fruits ripen over a long period from April to June.	Originated in Vista, California
Russian (Tatarica)	--	Fruit reddish-black, good quality, bushy and tall tree	Very hardy and drought resistant, mainly planted widely for wind breaks and wildlife food	Introduced into Europe from China about 1,500 years ago.
Shangri-La	*M. alba* x *M. rubra*	Fruits large, black, very large tree, heart-shaped leaves	Found hardy in U.S.D.A. Zones 7-9, good for the Deep South and other areas	Originated in Naples, Florida
Tehama (Giant White)	--	Fruits very large, white, plumpy, very sweet, large-leaved attractive tree	Probably best adapted to mild winter areas	Originated in Tehama County, California
Wellington	--	Fruits medium, reddish-black, good flavour, soft flesh	Ripens over a period of several weeks	originated in Geneva, New York

Table 2. Mulberry varieties/ genotypes being grown in India with peculiar characteristics

Varieties/ genotypes	Origin	Ecology/suitability	Source
Thar Harit	*Morus alba*	North India, arid and semi-arid region, fruit and juice purpose	Selection, Pushkar, Raj.
Thar Lohit	Morus rubra	North India, arid and semi-arid region, fruit and juice purpose	Chance seedling, ICAR-CIAH, Bikaner
CIAH-3	*Morus alba*	North India, arid and semi-arid region, fruit and juice purpose	Selection, Hisar, Haryana
Gurgaon Local	*Morus laevigata*	North India, irrigated condition	ICAR-NBPGR
Delhi Local	*Morus laevigata*	North India, arid and semi-arid region, fruit and juice purpose	New Delhi
Ajmer Local	*Morus laevigata*	Arid and semi-arid region	Selection, Ajmer, Raj.
Saharanpur Local-1	*Morus laevigata*	North India, irrigated condition	ICAR-NBPGR
Saharanpur Local-2	*Morus laevigata*	North India, irrigated condition	ICAR-NBPGR
MI-315	*Morus laevigata*	North India, arid region, fruit and juice purpose	CSGRC, Hosur, T.N.
MI-380	*Morus laevigata*	North India, arid region, fruit and juice purpose	CSGRC, Hosur, T.N.
MI 572	*Morus laevigata*	North India, arid region, fruit and juice purpose	CSGRC, Hosur, T.N.
Kanva-2	*Morus indica*	South India Irrigated condition	Selection from CSRTI, Mysore
Victoria-1	*Morus indica*	South India Irrigated condition	Hybridization (S30 x Berc 776) from CSRTI, Mysore
Chak Majra	Selection	Sub-temperate region	RSRS, Jammu
China White	Clonal selection	Temperate region	CSRTI, Pampore
Goshoerami	Introduced from Japan	Temperate region	CSRTI, Pampore
Anantha	Clonal selection	South India, rainfed	APSSRDI
Vishala	Clonal selection	South India, irrigated	KSSRDI, Thalaghattapura
Goshoerami	Introduced from Japan	Temperate region	CSRTI, Pampore
DD	Clonal selection from Natural population of variety Dehra Dun	South India, irrigated	KSSRDI, Thalaghattapura
MR-2	*Morus sinensis*	South India, Rainfed	Selection from open pollinated hybrids, CSRTI, Mysore
BC-259	Back crossing of hybrid of Matigare local x Kosen with Kosen twice	Hills of Eastern India	CSRTI, Berhampore
Tr-10	Triploid of Ber. S1	Hills of Eastern India	CSRTI, Berhampore
S-1	Introduction from Mandalaya, Myanmar	Eastern and NE India Irrigated	CSRTI, Berhampore
S-13		South India, rainfed	Selection from polycross progeny, CSRTI, Mysore
S-34	*Morus indica*	South India, rainfed	Selection from progeny (S30 x Berc 776), CSRTI, Mysore
S-36	*Morus indica*	South India, irrigated	Selection from CSRTI, Mysore
S-54	*Morus indica*	South India, irrigated onditionc	Developed through EMS treatment of Berhampore Local from CSRTI, Mysore
S-146	Selection from open pollinated hybrids	North India and Hills of Jammu and Kashmir, irrigated condition	CSRTI, Berhampore
S-1635	Triploid selection	Eastern and NE India, irrigated condition	CSRTI, Berhampore
S-7999	Selection from open pollinated hybrids	Eastern and NE India, irrigated condition	CSRTI, Berhampore
C776	Hybrid from English Black x Multiculis	Saline soils	CSRTI, Berhampore

Table 3. Morphological characteristics of mulberry genotypes at ICAR-CIAH, Bikaner

Characteristics	Mullberry genotype									
	Thar Lohit	Thar Harit	CIAH-3	Delhi Local	Gurgaon Local	Ajmer	SL-1	SL-2	MI-315	MI-380
Growth habit	Spreading	Spreading	Spreading	Upright	Upright	Upright	Upright	Upright	Upring	Spreading
Brach colour	Gray	Gray	Gray	Gray	Grayish yellow	Grayish yellow	Grayish yellow	Grayish yellow	Gray	Gray
Shoot type	Slightly curved	Slightly curved	Slightly curved	Straight	Slightly curved	Slightly curved	Straight	Slightly curved	Slightly curved	Straight
Bud colour	Reedish brown	Brown	Brown	Brown	Brown	Brown	Brown	Brown	Brown	Brown
Bud attachment	Slanting outward	Adhering to branch	Slanting outward	Slanting outward	Slanting outward	Slanting outward	Slanting outward	Slanting outward	Slanting outward	Adhering to branch
Mature bud shape	Round	Round	Round	Acute triangle	Round	Acute triangle	Acute triangle	Acute triangle	Acute triangle	Round
Leaf colour	Green	Green	Green	Green	Green	Green	Light green	Light green	Green	Green
Leaf length (with petiole) (cm)	11.2	12.1	12.3	15.2	14.2	17.5	11.5	15.2	14.4	11.3
Leaf lamina length (cm)	8.5	9.6	9.2	12.5	11.2	14.0	9.5	12.3	11.5	9.2
Leaf width	6.0	6.5	5.7	8.8	7.4	9.5	6.5	8.7	8.8	5.4
Leaf shape	Cordate	Cordate	Cordate	Cordate	Cordate	Cordate	Cordate	Cordate	Cordate	Cordate
Leaf lobes	Present	Absent	Present	Absent	Present	Absent	Absent	Absent	Present	Absent
Heterophylly	Present	Absent	Present	Absent	Present	Absent	Absent	Absent	Absent	Absent
Leaf surface (young leaves)	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Coarse	Smooth	Smooth
Leaf surface (mature leaves)	Rought	Smooth	Smooth	Rought	Rought	Rought	Rought	Rought	Rought	Smooth
Leaf pubescence	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent
Leaf apex	Acute	Acuminate	Acute	Acuminate	Acuminate	Acuminate	Acuminate	Acuminate	Acuminate	Acute
Leaf base	Cordate	Cordate	Cordate	Cordate	Cordate	Cordate	Cordate	Cordate	Cordate	Cordate
Leaf margin	Fine serrated	Coarsely serrated	Coarsely serrated	Coarsely serrated	Fine serrated	Coarsely serrated	Fine serrated	Fine serrated	Fine serrated	Coarsely serrated
Leaf arrangement	Alternate	Alternate	Alternate	Alternate	Alternate	Alternate	Alternate	Alternate	Alternate	Alternate
Order of phyllotaxy	1/2	1/2	1/2	1/2	1/2	1/2	3/8	1/2	1/2	1/3
Venation	Pinnate alternate	Pinnate alternate	Pinnate alternate	Pinnate alternate	Pinnate alternate	Pinnate alternate	Pinnate alternate	Pinnate alternate	Pinnate alternate	Pinnate alternate
Petiole groove	Present	Present	Present	Present	Present	Present	Present	Present	Present	Present
Fruit length (with pedicel) (cm)	4.9	4.1	2.6	5.6	4.8	4.1	4.0	5.5	2.8	1.6
Pedicel length (cm)	1.2	1.2	0.5	1.3	1.8	1.2	1.2	1.5	1.1	0.6
Fruit width (mm)	9.7	9.1	9.7	10.6	9.5	7.9	8.9	5.1	6.3	7.0
Fruit weight (g)	10.7	3.3	1.9	15.4	10.7	2.8	8.5	2.7	1.7	0.5
Fruit shape	Pendulous	Pendulous	Oblong	Pendulous	Pendulous	Pendulous	Pendulous	Pendulous	Oblong	Sub-globose
Fruit colour	Red	White	White	Red	White	White	White	White	White	White

Source: Krishna *et al.* (2018)

Table 4. Plant characteristics, frequency distribution, and example varieties/ genotypes of qualitative traits of mulberry at ICAR-CIAH, Bikaner

Plant descriptor	Range in expression	No. of Genotypes	Genotype
Growth habit	Upright	6	Delhi Local, Gurgaon Local,AjmerLocal, SL-1, SL-2, MI-315
	Spreading	4	Thar Lohit, Thar Harit, CIAH-3, MI-380
Branch colour	Gray	6	Thar Lohit, Thar Harit, CIAH-3, Delhi Local, MI-315, MI-380
	Grayish yellow	4	Gurgaon Local, Ajmer Local, SL-1, SL-2

Plant descriptor	Range in expression	No. of Genotypes	Genotype
Shoot type	Straight	3	Delhi Local, SL-1, MI-380
	Slightly curved	7	Thar Lohit, Thar Harit, CIAH-3, Gurgaon Local, Ajmer Local, SL-2, MI-315
Bud colour	Brown	9	Thar Harit, CIAH-3, Delhi Local, Gurgaon Local, Ajmer Local, SL-1, SL-2, MI-315, MI-380
	Reddish brown	1	Thar Lohit
Mature attachment	Slanting outward	8	Thar Lohit, CIAH-3, Delhi Local, Gurgaon Local, Ajmer Local, SL-1, SL-2, MI-315
	Adhering to branch	2	Thar Harit, MI-380
Mature bud shape	Round	5	Thar Lohit, Thar Harit, CIAH-3, Gurgaon Local, Ajmer Local, MI-380
	Acute triangle	5	Delhi Local, Ajmer Local, SL-1, SL-2, MI-315
Leaf colour	Green	8	Thar Lohit, Thar Harit, CIAH-3, Delhi Local, Gurgaon Local, Ajmer Local, MI-315, MI-380
	Light Green	2	SL-1, SL-2
Hertophylly	Absent	7	Thar Harit, Delhi Local, Ajmer Local, SL-1, SL-2, MI-315, MI-380
	Present	3	Thar Lohit, CIAH-3, Gurgaon Local
Leaf Surface (Mature)	Rough	7	Thar Lohit, Delhi Local, Gurgaon Local, Ajmer Local, SL-1, SL-2, MI-315
	Smooth	3	Thar Harit, CIAH-3, MI-380
Leaf Surface (Young)		9	Thar Lohit, Thar Harit, CIAH-3, Delhi Local, Gurgaon Local, Ajmer Local, SL-1, MI-315, MI-380
		1	SL-2
Leaf pubescence		10	Thar Lohit, Thar Harit, CIAH-3, Delhi Local, Gurgaon Local, Ajmer Local, SL-1, SL-2, MI-315, MI-380
Leaf apex	Acute	3	Thar Lohit, CIAH-3, MI-380
	Acuminate	7	Thar Harit, Delhi Local, Gurgaon Local, Ajmer Local, SL-1, SL-2, MI-315
Leaf base	Cordate	10	Thar Lohit, Thar Harit, CIAH-3, Delhi Local, Gurgaon Local, Ajmer Local, SL-1, SL-2, MI-315, MI-380
Leaf margin	Coarsely serrated	5	Thar Harit, CIAH-3, Delhi Local, Ajmer Local, MI-380
	Fine serrated	5	Thar Lohit, Gurgaon Local, SL-1, SL-2, MI-315
Order of phyllotaxy	1/2	8	Thar Lohit, Thar Harit, CIAH-3, Delhi Local, Gurgaon Local, Ajmer Local, SL-2, MI-315
	1/3	1	MI-380
	3/8	1	SL-1
Venation	Pinnate alternate	10	Thar Lohit, Thar Harit, CIAH-3, Delhi Local, Gurgaon Local, Ajmer Local, SL-1, SL-2, MI-315, MI-380
Petiole groove	Present	10	Thar Lohit, Thar Harit, CIAH-3, Delhi Local, Gurgaon Local, Ajmer Local, SL-1, SL-2, MI-315, MI-380
Fruit shape	Pendulous	7	Thar Lohit, Thar Harit, Delhi Local, Gurgaon Local, Ajmer Local, SL-1, SL-2
	Oblong	2	CIAH-3, MI-315
	Sub-globose	1	MH-380
Fruit colour	White	8	Thar Harit, CIAH-3, Gurgaon Local, Ajmer Local, SL-1, SL-2, MI-315, MI-380
	Red	2	Thar Lohit, Delhi Local

Source: Krishna *et al.* (2018)

Mulberry orchard establishment, care and management

Mulberry requires full sunshine hours and adequate space also. Pits sizes of 60x60x60 cm can be dug out during summer months in arid regions. Completely decomposed Farm Yard Manure should be mixed well with soils and pits are filled. Planting should be done at a spacing of 6 x 6 m in square system preferably during monsoon season or February-March months in arid region with assured irrigation facility. The trees should not be planted near a sidewalk. The fallen fruit will not only stain the walkway, but are likely to be tracked indoors. The trees are quite wind-resistant. The distance between trees should be 6 x 6 m. Semi hard wood cuttings give better result in respect of sprouting and survival. In situ budding during March to September months can also be done under arid and semi arid climate conditions. Irrigation should be done regularly after planting (Kumar and Haldhar, 2021). Although mulberries are somewhat drought-resistant but requires irrigation during dry seasons especially during fruiting period because, if the roots dry during dry period, the fruit may drop down prematurely. Irrigation using drip

technology is recommended for obtaining better fruit quality in arid ecosystem. There is no special pruning required after the branches have been trained to a good framework. However, removal of dead or overcrowded wood from plants is a regular practice. A mulberry tree can be kept to a tidy form by developing a set of main branches, and then pruning laterals up to six leaves in July in order to develop spurs near the main branches. It is not advisable to prune the trees heavily since the plant is inclined to bleed at the cuts. More than two inches in diameter cuts generally do not heal and should be avoided at all cost. The bleeding will be minimum when trees pruned in their dormant phase (https://crfg.org/wiki/fruit/mulberry; Kumar and Haldhar, 2021).

Application of organic manure, FYM @ 10 tonnes/ha as basal dose is necessa ry for successful establishment of the orchard. Thereafter, periodical fertilizer applications to the young growing plants should be done. Rainfed orchards receive optimum rains from the South-West monsoon. This should be taken as dvantage to make a good framework so that the plant may stand the drought months very well. Application of two doses (25 and 40 kg N/ha) of Ammonium Sulphate or Urea as nitrogen source should be done at an interval of three months. Thereafter, the normal fertilizer application programme could be done 100, 50, 50 kg N, P and K per hectare per annum). It may be applied in two equal split doses. The first dose should be applied in last week of August and the second dose in the last week of November (Kumar and Haldhar, 2021).

Evaluation of diverse germplasm of mulberry at ICAR-CIAH, Bikaner

For assessing feasibility of mulberry fruit production in hot arid ecosystem, fifteen genotypes had been collected at ICAR-CIAH, Bikaner from different places from the country including 02 genotypes from ICAR-NBPGR. Clonal plants of each genotypes were transplanted in the field for evaluation. CIAH Mulberry Selection 1 (purple red colour) and CIAH Mulberry Selection 2 (greenish white) was found superior over other genotypes and later on identified as Thar Lohit and Thar Harit at institute level, respectively. A wide range with respect to fruit length (0.9 cm to 9.4 cm) and weight (0.5 g -7.2 g) was recorded in these genotypes. The mulberry plants found to tolerate extreme cold and hot temperatures of the arid region. Very recently MI 572 germplasm was evaluated which showed promising response. Fruit was sweet in taste with slight sourness and reddish in colour. Average yield was recorded 1.51kg per plant after five years of transplantation. This genotype ripens two weeks earlier than Thar Lohit. The fruits harvesting started from second week of March, whereas Thar Lohit started from forth week of March (Kumar and Haldhar, 2021).

The first step of evaluation of genetic diversity in any plant species is morphological characterization of available germplasm. The most important morphological character for identification of any crop variety is fruit. Consumer gives more preference to external appearance of fruits such as shape, size and colour. Krishna *et al* (2018) studied ten mulberry genotypes belonging to three species *Morus rubra*, *M. alba* and *M. laevigata* at ICAR-CIAH, Bikaner for 29 morphological attributes and most of the characters had significant variations. They observed wide variations in fruit morphological characters with respect to fruit weight, fruit length and width among different genotypes. They found maximum differences in fruit weight, fruit shape, type of shoot and colour of bract. Minimum in phyllotaxy, leaf length, lamina length and bud colour and remaining traits showed intermediate type variations. They found varied fruit shapes from pendulous, oblong to subglobose. However, they reported more frequency of pendulous shape (seven genotypes), oblong in two genotypes and subglobose in one genotype. Fruit colour of studied genotypes was also varied from green-white to red (Table 3). Maximum fruit weight (15.4 g) was noted in genotype Delhi Local followed by 10.7 g in Gurgaon Local and Thar Lohit. Studied genotypes had more fruit weights which are desirable trait for future breeding programme of mulberry. Some findings of the study are similar to previous reports by researchers while some are disagreement which might be due to variability of studied mulberry genotypes/species and edapho-climatic factors of experimental site (Table 3, Krishna *et al.*, 2018).

Significant variations were also observed by Krishna *et al* (2018) with respect to plant characteristics, frequency distribution along with example varieties/ genotypes of qualitative traits of mulberry. Largest leaves were produced by genotype Ajmer Local followed by Gurgaon Local and Saharanpur Local-2 (both are at par each other). Similarly, leaf lamina was measured largest in Ajmer Local followed by Saharanpur Local-2 (Table 4).

Harvesting and yield

Changing of fruit colour is the key indices of fruit ripening of mulberry crop. When fruits turned white, red or black of mulberries *Morus alba*, *M. rubra* and *M. nigra*, respectively during maturity with shining

attractive fruit surface and pleasant arom they are ready for picking. In general, fruits are ready for picking during March and April months. The fruit are harvested by either spreading a sheet on the ground or shaking the limbs or by manual picking but first method is more common. Fruits are often harvested during morning hours so that timely disposal can be done because mulberries are highly perishable in nature. The harvested fruits are quickly disposed off in local markets due to very short shelf-life. Mullberry cultivar Thar Lohit gives 20-30 kg fruits yield/plant/ year on 8th year of planting under hot arid conditions of Bikaner, Rajasthan (Kumar and Haldhar, 2021). From mulberry orchard, 30-35 tonnes/ha of leaf every year can be harvested if mulberry is used for silkworm rearing. A farmer can get fodder, fuel and fertilizer by mulberry orcharding. Farmers in our country, feed their animals especially cows and goats with leftover branches and leaves from silkworm rearing after mixing it with straw. A mulberry orchard of one hectare can give on an average 12.1 tonnes per year twigs/ sticks which can be used for fuel purpose (FAO, 2016).

Pests and diseases of economic importance

In general mulberry crop does not attack by diseases and pests. Sometimes, younger plants are damaged by termites particularly during dry period under arid environment. Sandy soils of arid zones are more prone to termite attack. Termites build an earthen cover on the stem of plants which may cause drying or killing of plants and ultimately reduction in yield. There are some recommendations for management of termites. Sincere observation and destruction of termite colonies especially by killing queen termite, drenching of established plants at the base with 50 ml chlorpyriphos 20 EC and application of mounds with 50 ml chlorpyriphos 20 EC. The ripe fruits of mulberry are colourful and very attractive, therefore, some attack of birds observed but there are enough fruits remained for picking. There are many birds including crows, sparrows, parrots etc cause substantial damage by feeding of ripening fruits. The bird species can be effectively managed by using visual repellents like bird scaring ribbons in the orchards and to frighten them by making sounds (Kumar and Haldhar, 2021). There are some minor pests also attack on mulberries such as Bihar hairy caterpillar (*Spilarctia oblique*), mealy bug (*Maconellicoccus hirsutus*), leaf roller (*Diaphania pulverulentalis*), short horned grasshopper, scale insects, thrips, jassids, etc. Besides pests, some diseases are also affecting mulberry crop. They are root rot, collar rot and dieback, cutting rot, stem canker, leaf spot, powdery mildew, leaf rust, leaf blight and bacterial blight which cause considerable loss to mulberry crop right from nursery stage to standing crop.

REFERENCES

Baidya, A. and Chatterjee, M. 2020. Studies on the seasonal incidence of different insect pests and their natural enemies of Mulberry and their correlation with weather parameters under Terai Region of West Bengal. Journal of Entomology and Zoology Studies, 8(1): 1235-1239.

Food and Agricultural Organisation, 2016. Mulberry cultivation and utilization in India (https://www.fao.org/3/X9895E/ x9895e04.htm, retrived on 09 December, 2022).

Hosseini, A.S., Akramian, M., Khadivi, A., Arjmand, H.S., 2018. Phenotypic and chemical variation of black mulberry (*Morus nigra*) genotypes. *Ind. Crops Prod*.,117: 260–271.

https://crfg.org/wiki/fruit/mulberry. (Retrived on 08/12/2022).

https://www.statista.com/statistics/1025884/india-mulberry-plantation-area (Area of mulberry plantation in India from financial year 2013 to 2022).

Kadam, R.A., Dhumal, N.D. and Khyade, V.B. 2019. The Mulberry, *Morus alba* (L.): The Medicinal Herbal Source for Human Health. *Int. J. Curr. Microbiol. App. Sci*., 8(4): 2941-2964.

Krishna, H., Singh, D., Singh, R.S., Kumar, L., Sharma, B.D. and Saroj, P.L. 2018. Morphological and antioxidant characteristics of mulberry (*Morus spp.*) genotypes.

Kumar, K. and Haldhar, S.M. 2021. Suitable genotypes of underutilized fruit crops for pest management. *In*: Pest management indryland horticultural crops (Eds. Haldhar, S.M. and Maheshwari, S.K.). Biotech Books, Darya Ganj, New Delhi. pp.155-171.

Saroj, P.L., Ram, C. and Kumar, K. 2020. Arid horticultural crops: Status and opportunities under changing climatic conditions. *Indian J. Plant Genet. Resour.,* 33(1): 17-31.

Vijayan, K., Srivastava, P. P., Raju, P. J. and Saratchandra, B. 2012. Breeding for higher productivity in mulberry. *Czech J. Genet. Plant Breed.*, 48: 147-156.

Vijayan, K., Tikader, A., Weiguo, Z., Nair, C.V., Ercisli, S., Tsou, C.H. 2011. Morus. In: Kole, C. (Ed.), Wild Crop Relatives: Genomic and Breeding Resources. Springer Berlin Heidelberg, pp. 75–95.