Review Article

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Genetic resources of underutilized fruits of arid and semi-arid zones: A review

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ABSTRACT

Indian subcontinent is one of the biodiversity regions in the world. These are three bio diversity hotspots namely Northern Eastern Hill region, North western Himalayan region and Western Ghats ate situated in this region. Apart from these three hotspots, several other regions particularly the semi-arid and arid regions also have rich in diversity of plant and animal. The low and erratic rainfall, high evapo-transpiration, extreme temperature regimes, poor soil conditions of these regions helped to evolve several plant species which can grow well under stressful edaphic and environmental conditions. These perennial plant species have played a major role in the food sustainability and livelihood of these regions. Traditionally most of these species were collected from the forest. The recent awareness about potential of ecologically fragile lands for cultivation of fruit trees has not only opened up scope for providing economic sustainability for the natives, especially small farmers, but also for bringing new areas under fruit production. The underutilized fruit crops such as *bordi* (*Ziziphus rotundifolia*), *jharber* (*Z. nummularia*), lasoda (*Cordia myxa*), *kair* (*Capparis decidua*), phalsa (*Grewia subinaequalis*), *gangana* (*Grewia tenax*), bael (*Aegle marmelos*), jamun (*Syzygium cuminii*), *pilu* (*Salvadora oleoides and S. persica),* karonda (*Carissa carandas*), wood apple (*Feronia limonia*), mulberry (*Morus* spp.), manila tamarind (*Pithocelobium dulce*), etc. are found in these regions. A vast diversity of these species exists in the region. The genetic resources of these fruits are rapidly declining due to climate change, urbanization and change in farming systems. There is need to conserve these genetic resources for their utilization for crop improvement programme and future uses. Several attempts have been made by research organizations to collect, conserve and utilize the genetic resources of these underutilized fruit species. Several promising varieties and lines have been identified for enhancement of production, and productivity of these crops. The status of plant genetic resources of some of the important underutilized fruit species of semi-arid and arid regions have been compiled in the review paper.

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Introduction

In India, arid and semi-arid regions cover approximately 15.8% and 37% respectively, which is roughly half of the total geographical area (about 3,287,263 km^2). The arid regions of Rajasthan, Gujarat, Punjab and Haryana while the semi-arid region is spread over a large tract of central India which includes part of Madhya Pradesh, Maharashtra, Karnataka, Telangana, Tamil Nadu, Odisha and Andhra Pradesh. The underutilized fruits may be categorized in two groups i.e. indigenous and exotic. India has a rich and varied heritage of biodiversity, encompassing a wide spectrum of habitats from tropical rainforests to alpine vegetation and from temperate forests to coastal wetlands. Out of 18 biodiversity hotspots identified in the world, four hotspots, i.e. Western Ghats, Eastern Himalayas, Western Himalayas, and Nicobar Islands, are in India.

Several fruit plant species have originated in the Indian subcontinent. India is the centre of origin of bael, aonla, ber, jamun, mahua, phalsa, lasoda, karonda, wood apple and several other wild fruits. Some of these fruits have gained popularity in the past few decades but the majority are still not grown in large area. Several minor fruits such as *Annona* spp., manila tamarind, prickly pear, dragon fruit etc. were introduced during last few centuries. Some of adopted to the climatic conditions of India and have become major fruits. The genetic resources of indigenous species are under threat due to urbanization, changes of farming system and livelihood patterns. The conservation and utilization of genetic resources of these crops are essential to enhance productivity, promote commercialization, and develop climate-resilient horticultural systems (Meghwal and Singh, 2024).

Conservation strategies include both *in-situ* and *ex-situ* approaches. In-situ conservation ensures theprotection of genetic diversity within natural ecosystems and traditional farming systems, whereas *ex-situ* conservation involves the conserving of germplasm in seed banks, field gene banks, and cryopreservation facilities. Advances in molecular characterization techniques have further strengthened efforts to identify and preserve elite germplasm, facilitating breeding programs aimed at improving fruit quality, yield, and stress tolerance. With increasing concerns about climate change and desertification, the role of arid and semi-arid fruit crops in sustainable agriculture is gaining attention. Systematic research, farmer participation, and policy support are crucial to harnessing the full potential of these crops for future food security and environmental resilience.

Efforts led by institutions such as the ICAR-NBPGR, ICAR-CIAH and agricultural universities focus on germplasm collection, characterization, and conservation to safeguard the genetic diversity of these crops. Most of ICAR institutes and agricultural universities etc. are involved in the collection, evaluation and utilization of fruit genetic resources. Being a National Active Germplasm Site (NAGS) for arid fruits, the ICAR-CIAH, Bikaner, Rajasthan, is maintaining the largest repository of the germplasm of arid and semi-arid regions. NRC for Pomegranate, Solapur has a large collection of pomegranates, while the ICAR-IIHR is maintaining a large germplasm of Annona, pomegranate, jamun, wood apple and kaith. The crop-wise status of collection, conservation, and utilization of germplasm of some important fruit crops of the arid and semi-arid zone is described as follows.

Bael (*Aegle marmelos* (L.) Correa)

Bael occupies an important place among the indigenous fruits of India. It has been known in India since prehistoric times. It is called *Bilva* or *Sriphal* or *Shivadruma* in Sanskrit and is considered auspicious, sacred, and the emblem of prosperity. The history of the bael has been traced to Vedic times (2000 BC-800 BC in *Yajurveda* and in Buddhist and Jain literature (800 BC-325 BC). It belongs to the family Rutaceae. It is also known as Bengal-quince, golden apple, and stone apple. The chromosome number is x=9 and 2n=36.

There are no detailed cytogenetic studies on bael, however, few reports from Punjab plains, Shivalik Hills and Panchmadi Hills revealed the existence of diploid (2n=8) and tetraploid cytotypes (2n=36). Bael is native to Indian subcontinent and its origin is the Eastern Ghats and central India. It is mainly found growing in tropical and subtropical regions. The tree is also found as a wild, in the lower ranges of the Himalayas up to an elevation of 1000 m. It is found growing in neighbouring countries like Nepal, Sri Lanka, Pakistan, Bangladesh, and most of the Southeast Asian countries, but is cultivated only in India.

Genetic resources

The genus *Aegle* is one of the monotypic genera of the orange subfamily with deciduous leaves. One more species *A. decandra* Fern Vill. was reported under the genus *Aegle* according to World Checklist of species of plants (WCSP), global species resources. *A. decandra* is native to the Philippines. The rich diversity of bael present in India in cultivated and uncultivated areas has been collected and maintained. However, genetic erosion of these resources is high due to severe deforestation, natural calamities and other land use changes that are occurring in the country at an unprecedented rate, therefore, its con-

servation has become necessary. Naturally growing bael trees are found in U.P, Bihar, Jharkhand, M.P., Orissa, West Bengal and Chhattisgarh. In these areas, great diversity could be observed which needs to be conserved *in-situ* or be collected, conserved and exploited. In Uttar Pradesh, Ayodhya, Sultanpur, Gonda, Jaunpur, Deoria, Pratapgarh, Allahabad, Varanasi, Mirzapur, Etawah, Mathura and Agra are the districts where many improved types are growing or planted in backyards (Pandey *et al*., 2013).

Rai and Dwivedi (1992) and Vishal Nath *et al.* (2003) reported a wide range of bael genetic diversity in Northern and Eastern Central India. Apart from the morphological characters, wide variation exists for traits such as fruit shape and size; bearing habit; pulp colour, texture, fibre content, sugar content, mucilage content; number of seeds per fruit, gumlocules; thickness of pericarp, etc. Among the local types, Ayodhya, Kagzi Etawah, Kagzi Gonda, Sivan Large, and Mirzapuri are popular in UP due to their good yield potential and fruit quality. The bael genotypes available in Karnataka, Andhra Pradesh, and Telangana are different from the genotypes available in North Indian plains. These have smaller leaves and leaflets. The fruits are smaller and non-edible because of higher saponin content (Tripathi *et al*., 2017).

Collection

In India, there are two prominent types of bael. One is the small-fruited type having acrid pulp and many seeds, high mucilage and fibre content and the second is the large-fruited type with a thin shell, few seeds, less fibre and mucilage and sweet pulp. Bael germplasm is collected and conserved by ANDUA&T, Ayodhya; GBPUA&T, Pantnagar; ICAR-CISH, Lucknow; ICAR-CIAH, Bikaner; ICAR-CAZRI, Jodhpur; ICAR-NBPGR-Regional Station, Jodhpur; ICAR-IIHR, Bengaluru. The collections from Bihar, Jharkhand are conserved at ICAR-NBPGR-RS, Jharkhand (Dhakar *et al*., 2019). ICAR-IIHR, Bengaluru explored Karnataka, Andhra Pradesh, Telangana and collected more than 100 samples (Tripathi *et al.*, 2017).). The bael germplasm is also collected at several other research stations. There may be many duplicates in the germplasm at different stations as many samples were collected from secondary sources. The available bael accessions are conserved at the field gene banks of the above-mentioned research centres.

Conservation

Bael germplasm is conserved using *in-situ* and *ex-situ* approaches. The bael accessions are conserved in *ex-situ* at the field gene banks of at several research institutes (Table 1). In efforts of conservation germplasm under gene bank under laboratory conditions at low temperature is also is in progress. The seed of bael are intermediate type and can be stored for 24-36 months at ambient temperature (24-36°C). The bael seeds can be cryopreserved and stored for a long time. Bael seed loses most of its viability (germination 1.07%) when the critical seed moisture level falls to 4.4%. The loss of viability due to exposure of liquid nitrogen was 11.60%. The viability of seed was 70% and 65.5%before and after cryo-conservation, respectively (Malik *et al.,* 2010). The seeds show chilling sensitivity and most seeds lost viability after 12 months of storage at -20^{O}C.

Only a few studies have reported on the collection and maintenance of bael germplasm in Sri Lanka, Pakistan, and Bangladesh. The collections of Pakistan and Bangladesh are genetically similar to the collections available in Northern India.

Table 1. Bael germplasm maintained at different research centres

Name of the organization	Accessions
Acharya Narendra Dev University of Agriculture & Technology, Ayodhya, Uttar Pradesh	22
Govind Ballabh Pant University of Agriculture & Technology, Pantnagar, Uttarakhand	10
ICAR-Central Institute for Subtropical Horticulture, Lucknow, Uttar Pradesh	22
ICAR-Central Institute for Arid Horticulture, Bikaner, Rajasthan	16
Dryland Agricultural Research Station, Anantapur, Andhra Pradesh	12
Regional Research Station, Aruppukottai, Tamil Nadu	05
Dryland Agricultural Research Station, Sardarkrushinagar, Gujarat	12
ICAR-National Bureau of Plant Genetic Resources, New Delhi	05
Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra	06
ICAR-National Bureau of Plant Genetic Resources, Regional Station, Thrissur, Kerala	57
ICAR-Indian Institute of Horticultural Research, Bengaluru	117
ICAR-NBPGR, RS, Ranchi	17
ICAR-CIAH, CHES, Godhra	222

Evaluation

Rai *et al.* (1991) reported on bael variability available in India observed at different locations. Lal (2002) evaluated

12 genotypes collected from Jaipur, Rajasthan and found that 8 genotypes produced fruits of excellent quality under semi-arid conditions, and two genotypes were identified for further testing. Extensive characterization was done by Jaiswal and Mishra (1998). The wild and cultivated trees growing at the above-mentioned places were reported to be diploid with normal meiosis with 92-98% pollen fertility. The trees possessing large leaves and fruits were found to be tetraploid. In addition to tree morphological characters, wide variability was found in fruit size and shape, bearing habit, flesh colour, texture, fibre content, sugar content, mucilage content, etc, in different parts of the country (Singh *et al.*, 2011; Nath *et al.*, 2003). In the Jaunpur area of UP, among the very old naturally growing bael trees with many seeds, gum locules and thick pericarp were found (Misra *et al.*, 2000). Some promising lines have been identified, but still need to be tested rigorously (Pareek and Nath, 1996; Vishal Nath *et al.,* 2003).

Bael collections made at ICAR-NBPGR were characterized for various physicochemical characters and the heaviest fruits with the highest TSS were recorded for accession IC546120, followed by those in IC54613.In West Bengal, collection and evaluation of over 1200 bael trees were initiated in 1994 for various traits such as yield, fruit weight, fruit shape etc., and six genotypes were identified as superior clones and are being conserved at the Faculty of Horticulture Research Station, Kalyani (Mitra *et al.*, 2010). Tripathi *et al.* (2017) evaluated 115 accessions of bael collected from Karnataka, Andhra Pradesh, Telangana, Maharashtra and North India. The growth habit ranged from spreading to upright. Overall, accessions collected from Karnataka and Telangana had smaller fruits and a more soapy flavour and taste but were found free from cracking and even fruit borer. The latter need more studies to confirm so that these may be used in the programme to improve these traits. Chaturvedi *et al.* (2023) evaluated 24 bael genotypes from two agroecological zones of India using morphological (13 quantitative traits), biochemical (9 attributes), and molecular (10 SRAP primers) characterization. Fruit and pulp weights varied from 79.0 to 1478.8 g and 15.0 to 894.3 g, with mean values of 448.67 g and 233.3 g, respectively. The fruit pulp exhibited high phenol (11.65–24.38 mg GAE/g fw) and flavonoid (12.32–74.63 mg CE/g fw) contents, indicating notable antioxidant potential.

Five elite bael accessions were evaluated at Fruit Research Station in Sri Lanka and considerable variation was observed for the variation of the fruit size, pulp, organoleptic preferences, etc. and fruits from Rambukkana and Polonnaruwa-Supun lines were found to be the most preferred (Pathirana *et al.*, 2020). Presently the selection of the selected genotypes is the only method used to develop the varieties. The hybridization and mutation breeding may be used to develop breeding lines and varieties with desirable traits in future. The present varieties are a selection from the landraces or seedlings progenies.

Varietal development

Elite selections have been made at ANDUA&T, Ayodhya (NB-4, 5, 7, 9, 16, 17); GBPUA&T, Pantnagar, ICAR-CIAH, Bikaner and CHES(CIAH), Godhra (Goma Yashi, Thar Divya, Thar Neelkanth, Thar Prakriti), ICAR-CISH, Lucknow (CISH B-1 & 2) which are becoming popular for commercial cultivation. Other institutes like FSRCHPR, Ranchi one genotype Swarna Vasudha and Dhara Road from CAZRI, Jodhpur and GB PAUT viz., Pant Nagar promising one are Pant Aparna, Pant Shivani, Pant Sujata, Pant Urvashi released for commercial orcharding.

Kaith (*Feronia Limonia L. syn. Limonia acidissima* L, *Limonia elephantum* (Correa), *Schinus limonia* L.

Wood apple (kaith) is adrought-resistantfruit tree species. It is known as *kathbel* in Bengali, *kothu* in Gujarati, *beldahannu* in Kannada, *kavit* in Marathi, *Vilaljam* in Tamil and Malayalam, *Kaith*, *katbel* in Hindi, and *Kapittha,Dadhiphal* in Sanskrit, wood apple/curd fruit in English. *Kaith* is a multipurpose tree species, valued for its nutritious edible fruits, gum, wood, and alkaloids. It is said to have many medicinal properties. The fruit pulp is sour-sweet in taste and full of small seeds. It is rich in nutrients suchas carbohydrate, protein, fat, fibre, vitamins (A, B_1, B_2, B_3 and C) and minerals (iron, calcium, phosphorus, zinc, manganese). It belongs to the sub-family Aurantioideae of the family Rutaceae. Kaith is a deciduous tree which grows up to 20 m high.

Kaith is native to Indian subcontinent. It is also found growing in Pakistan, Bangladesh, certain parts of Sri Lanka, Pakistan, Thailand, Malaysia, Cambodia and some other countries of Southeast Asia. In India, it is grown in Maharashtra, Tamil Nadu, Andhra Pradesh, Madhya Pradesh, Karnataka, Telangana, Rajasthan and Gujarat. It grows on barren lands, bunds of field, and the forest areas. The fruits are collected from these trees and sold in the market. The fruits are available in the market from October to March, sometimes up to June.

Genetic resources

Feronia is a neglected crop, and systematic efforts to collect of Feronia are yet to be taken. Isolated efforts were made at several institutes and universities to collect Feronia. Several types of Feronia are found in wild and in cultivated

land in Karnataka, Maharashtra and Madhya Pradesh. As *Feronia* is monogenic, there are no related species.

Collection

Most of the trees are of seed origin and exhibit considerable variation which can be used for making selection of superior types. There are two forms - one with large, sweetish fruits and the other with small, acidic fruits. ICAR-IIHR, Bengaluru maintaining 16 accessions and ICAR-CIAH, CHES, Godhra is maintaining 16 accessions. At BCKV, Kalyani 07 accessions are being maintained (Ghosh *et al.*, 2012).

Conservation

Very little work is done on Feronia conservation, with only a few accessions maintained in field gene banks at a few institutes. As wood apple seed can only be stored for about 90 days without serious loss of viability. Since there have been no explorations/ surveys, neither genetically diverse samples nor elite material has been conserved. This species has been neglected and has not received the attention it deserves, mainly due to difficulties in conducting research, e.g., their large size, prolonged juvenility, long life cycles, irregular flowering, and lack of standardized cultivation practices

Evaluation

Precocity in bearing, less spine intensity, earliness, regular bearing, uniform maturity, the dwarf stature, large fruit with more pulp and fewer seeds are some traits. Two types of kaith, i.e., one with larger fruits sweeter in taste and another smaller with acidic fruits, are found in all the growing areas. Since this is a monogenic species, the variability is less compared to other fruit species of family Rutaceae. As noted earlier, very few efforts have been made to collect kaith genetic resources from different regions of the country. At ICAR-IIHR, Bengaluru, more than 16 collections were made from Karnataka, Telangana, and Andhra Pradesh. Among them, two collections were found superior to others by being high-yielding, regular-bearing, large-fruited, with higher TSS (>18°Brix), brown colour pulp, and sour-sweet taste (Tripathi, 2020). Ghosh *et al.* (2012) collected and characterised seven samples wood apple, trees with varied ages (13 and 70 years) for different traits viz. yield (650 to 1085 kg/plant), fruit weight (130 to 225g), pulp percentage (42.9 to 60.6%), T.S.S. (15.0 to 18.4°Brix), acidity (1.7 to 4.6%) and total sugar content (5.1 and 14.3%).

CHES, Godhra was evaluated for traits like precocity in bearing, less spine intensity, earliness, regular bearing, and dwarf stature of the tree. The fruit have strong aroma. The fruit weight ranged between 145.52g to 431.23g (Yadav *et al.*, 2018). In wood apple, *in-situ* evaluation of accessions from Telangana revealed that the accessions identified with desired fruit traits include AS/SB-1 (Fruit weight >250 g), AS/SB-8, AS/SB-13, AS/SB-19 (>65% pulp recovery), AS/SB-8 (high TSS 20.8°Brix) and AS/SB-7 (low acidity of 2.28%). Based on yield and fruit qualities, superior wood apple tree (CKBR-1) from Karikere in Chitradurga district was identified from field of a farmer. The tree is nearly free of thorns, bears large fruits (350 g) with high pulp recovery (62%), TSS (19°Brix) and moderate acidity (2.87%). Fruiting occurs during February-June. Average yield is 300 kg per tree per year. The source of resistance to abiotic and abiotic stress has not been identified. There is a need to select elite lines that may be used as parents for future improvement programmes. Presently, the selection of the genotypes from the variability in forests and stray land is the only method that can be used to develop the varieties.

Varietal development

Some elite lines have been collected and multiplied at some organization. A few varieties have been identified, including Yellora by VNMKV, Parbhani (MS), Thar Gaurav and Thar Prabha by ICAR-CIAH, CHES, Vejalpur, PDKV Pratap by PDKV, Akola (MS) and PKM-1 from TNAU, Periyakulam.

Karonda (*Carissa carandas*)

Karonda is native to India and occurring throughout country. It grows well arid tropics and subtropics and produces attractive coloured edible fruits. It also grows successfully on marginal and wastelands. It thrives well under rain-fed crop conditions and needs hardly any care and gives satisfactory fruit yield with the minimum management. It is also used as live fencing around the orchards. Ripe fruits are sub-acidic to sweet with peculiar aroma. The fruits are eaten as a dessert when ripe. Mature fruits contain a high amount of pectin and are used for the preparation of different products such as jelly, jam, squash, sauce, syrup, etc. *C. carandas* (2n=22) belongs to family Apocynaceae. It is a large evergreen shrub with a short stem grows to a height of 3-6 meters.

C. *carandas* and *C. spinarum* are native to India while *C. grandiflora* is native to South Africa. *C. carandas* is also grown in Sri Lanka, Myanmar, Thailand and Peninsular Malaysia. In India, it is found wild in the Western Ghats, Konkan area of Maharashtra and throughout the semi-arid regions. It is usually found in home gardens, as a hedge along farmer's fields and orchards and grown for commercial purpose. *Carissa* species is of socio-economic importance in the tribal areas of Gujarat, Maharashtra, Rajasthan, and Madhya Pradesh.

Genetic resources

It is found growing in Maharashtra, Bihar, West Bengal, Chhattisgarh, Orissa, Gujarat, Madhya Pradesh, Rajasthan

and in the Western Ghats Karonda occurs growing naturally in several areas. In Maharashtra, it is cultivated scattered in submontane areas like Kolhapur, Ratnagiri and Pune district. It grows wild in most South Asian countries like in the lowland rain forests of Sri Lanka. Although it grows throughout India, the maximum variability is found in the states of Maharashtra, Bihar, West Bengal, Chhattisgarh, Orissa, Gujarat, Madhya Pradesh, Rajasthan and in the Western Ghats. Aravalli Hills of Haryana and Rajasthan (mainly the Mt. Abu), Chittorgarh and Sirohi districts are rich in karonda diversity.

It has been widely collected from Maharashtra; 212 collections have been made from Kolhapur (Sawant *et al*., 2002) and are maintained at the College of Agriculture, Kolhapur. A total of 111 samples were collected from 45 locations in western Maharashtra, Marathwada, and Goa, which are classified based on fruit characters. At ICAR-NBPGR, germplasm of *C. congesta* and *C. spinarum* has been collected from Rajasthan, Gujarat, and Madhya Pradesh. *C. grandiflora,* which maintained in the field gene bank at the Regional Research Station, PAU, Abohar, was also added to the ICAR-NBPGR gene bank.

The genus Carissa has nearly 30 species originating in South Africa, Australia, tropical Asia and Malaysia. Different species of Carissa are grown for their small berry-like edible fruits and as closely branched spinous hedges. Some species are also cultivated for ornamental purposes. Apart from *C. carandas*, other important species are *C. spinarum*L*, C. inermis* Vahl.*, C. suavissima* Bed.*, C.acuminate* DC*, C. bispinosa* Desf., *C. congesta* Wight, *C. edulis* Forssk.*, C. grandiflora* and C. *macrophylla* Wall. ex G. Don. These are spread over subtropical and tropical Asia and Africa. Most of them have edible fruits that are used by the native people.

Collection

Germplasm of karonda and its wild species are being maintained at various field gene banks at MPKV Rahuri, RS Kolhapur; ICAR-CAZRI, Jodhpur; ICAR-CISH, Lucknow; ICAR-CIAH, Bikaner; ANDUA&T, Ayodhya; CCSHAU, Regional Research Station, Bawal; ICAR-NBPGR Regional Station, Jodhpur; CHES (ICAR-IIHR), Chettalli and GBPUA&T, Pantnagar (Table 2).

Table 2. Karonda germplasm at different locations

Institute	Accessions
ICAR-CIAH, Bikaner	8
ICAR-CIAH, CHES, Godhra	40
ICAR-IIHR, CHES, Chettalli	31
MPKV, Rahuri, RS, Kolhapur	212
CCS HAU, RRS, Bawal	4
ICAR-CISH, Lucknow	25

Conservation

In-situ conservation of karonda has been done at various locations. Although seeds are the major source of propagation, they can be multiplied to someextent by rooting cuttings and layering. Thus, both sexually and vegetatively propagated plants are conserved in field gene banks. However, seeds have short viability and should be sown soon after extraction from fruits. The studies conducted at ICAR-NBPGR demonstrated karonda's intermediate nature of seed. Fresh seeds exhibited 18.4% moisture and 72% germination and dropped by 50% in 3 months. Seeds showed slight desiccation sensitivity and high freezing tolerance as on desiccation to 9% moisture and 12% decline in viability was recorded. Seeds desiccated to 6-8% moisture showed 65-70% germination after LN exposure. Fourteen accessions of *Carissa* spp. (9 of *C. carandas*, 1 each of *C. edulis* and *C. grandiflora,* and 3 of *C. spinarum*) are in cryo-storage at ICAR-NBPGR, New Delhi (Malik *et al.*, 2010).

Evaluation

The major concerns are smaller fruit size, thorniness, high latex, acidity, low TSS, cracking and more number of seeds per fruit. High yield potential, big-sized fruits with attractive skin colour higher pulp content, a smaller number of seeds, high TSS with low in acidity, dwarf stature with less spine intensity, resistance for major diseases and pests are desirable traits. A survey of karonda in eastern Uttar Pradesh identified 4 types of fruit, viz. green, white with a pink blush, green with purple blush and maroon (Kumar and Singh, 1993). Average fruit weight ranged from 1.6 to 4.7 g and an average number of seeds per fruit from 5 to 11. TSS ranged from 3 to 4.5%, ascorbic acid from 10.26 to 17.94 mg/100 g, reducing sugars from 0.93 to 2.4% and non-reducing sugars from 0.57 to 1.33%. Mishra *et al.* (2007) developed three varieties by selection viz., Pant Manohar, Pant Sudarshan, and Pant Suvarna. At ICAR-CAZRI, Jodhpur, collected a wide range of samples of *Carissa* in 2000-2001 and three genotypes were identified to be the high yielding and to be released shortly (Anonymous, 2011).

Sixteen distinct karonda genotypes were identified from the germplasm collected from western Maharashtra. At MPKV, Rahuri four promising genotypes were identified (Karale *et al*., 1989; Karale *et al*., 1990)). Singh *et al.* (1999) identified 4 genotypes of karonda based on the colour of the fruits and grouped in to, green, green with purple blush, white with pink blush and maroon. Tripathi *et al.* (2014) evaluated 45 karonda accessions collected from the Western Ghats and some parts of South India. The number

of fruits ranged from 84 to 3540 fruits/ plant. The yield ranged from 0.93 kg/tree to 69.50 kg/ plant. The highest yield was recorded in K-I-2 (69.56 kg). The fruit weight was highest in K -I-3 (21.69 g). Pulp percent ranged from 66.41 to 92.58 per cent. The TSS varied from 11.6° Brix in K-I-8 to 18.9°Brix in K-V-4. These superior lines have big size fruit (12- 16g), few seeds and higher TSS.

Varietal development

Elite selections have been made at GBPUA&T, Pantnagar (Pant Suvarna, Pant Manohar, Pant Sudarshan); BSKKVV, Dapoli (Konkan Bold), ICAR-CAZRI, Jodhpur (Maru Gaurav), ICAR-IIHR, CHES-Chettalli (CHES- K-II-7&CHES- K- V-6) and CIAH, Bikaner (Thar Kamal) which are gaining popularity for commercial cultivation. The varieties and promising line developed through selection are, CHES-K–2, CZK-2011, CZK-2022, CZK-2031 CISH Kr-11, CHESC-K-2-7 and CHESC-K-35.

Kair (*Capparis decidua* (Forssk.) Edgew)

Kair, Caperberry, Bare Caper is an important indigenous multipurpose shrub of a hot arid ecosystem with the ability to survive in various unattended and unprotected habitats (Singh *et al*., 2005). It is found growing in arid and semi-arid tracts. *Kair* is found growing along farm boundaries, pastures and wasteland and can survive in various habitats. It produces edible fruits which are relished by the local population. The fruits are rich in carbohydrates, proteins and minerals. The cured dried fruits are used in vegetable preparations and for pickling. The species play ecological roles in providing vegetative cover, improving soil fertility, preventing soil erosion and promote biodiversity in addition to its economic significance.

It belongs to family Capparaceae. *Kair* is a straggling glabrous shrub with zigzagging green branches (phylloclade) with a pair of straight spines. Exact origin of *kair* is unknown but it is distributed naturally in a wide area comprising of India, Iran, Jordan, Mauritania, Chad, Egypt, Ethiopia, Niger, Nigeria, Pakistan, Senegal, Somalia, South Africa and Sudan, the area of its natural distribution. Ker grows wild and unattended throughout India's arid northwest regions. In India, it is mostly found in Rajasthan and Gujarat (Singh and Singh, 2011). It is a source of income to people in the drier regions of Rajasthan and Gujarat. Several thousand tonnes of fruits are produced in the Jodhpur and Bikaner districts of Rajasthan (Chandra *et al*., 1994).

Genetic resources

The genetic variability is spread over dry arid regions of western India particularly in drier areas of Rajasthan and Gujarat in India and in other countries of its natural distribution. Natural population exhibits marked variation in plant types, spines, canopy (spread and compactness), flowering (time of flowering, the colour of flower), and fruiting (size and colour of fruits) characters. Two distinct plant types were observed, a shrub with large canopy and small tree form having more than 5 m height. Flowers are light red to scarlet red, and occasionally few plants have yellow flowers. The size and colour of mature fruits varied considerably. The collected accessions exhibit wide range of variability for fruit diameter, fruit weight, number of seeds per fruit, test weight and canopy characteristics. There are several species in the genus *Capparis*, namely *C. spinosa, C. orientalis, C. sicula, C. aegyptia, C. ovate* etc., which are found in Spain, Morocco, Syria, etc. Amplified Fragment Length Polymorphism (AFLP) revealed low genetic distance among *Capparis* species.

Collection

Various studies carried out on natural populations of *C. decidua* indicate that it possesses considerable genetic diversity (Abdel-Mawgood *et al*., 2005; Singh *et al*., 2007; Vyas *et al*., 2009) but its systematic utilization in genetic improvement has been very limited. The collection of *kair* variability in various hot and drier regions of Gujarat, Rajasthan and Haryana are being taken at CAZARI, Jodhpur; CIAH, Bikaner; CCS HAU RRS, Bawal and ICAR-NBPGR RS, Jodhpur.

Conservation

Conservation of *kair* germplasm is presently being undertaken using *ex-situ* field gene banks at ICAR-CAZRI, Jodhpur (20 accessions), CIAH, Bikaner (65 accessions) CCS HAU RRS, Bawal (57 accessions) and ICAR-NBPGR RS Jodhpur (22 accessions). Micro propagation of *kair* has been successfully reported by with 3-5 shoots per explants using *in-vitro* culture of nodal explants. Germination and seedling growth showed significant variations among accessions. The germination ranged 41.6–93.4 % and survival varied from 44.2 to 76.8%. Total 88 accessions of *kair* are maintained at cryo-storage of ICAR-NBPGR, New Delhi (Malik *et al.*, 2010). Ahlawat *et al.* (2018) reported that synthetic seeds of *Capparis* was stored for 30 days at 4°C and 8°C and moisture content 69.7% and 50.9% respectively, which was similar to the highest germination. The encapsulated shoot tips of *Capparis decidua* showed maximum regrowth frequency on media MSA and responded with almost 100% conversion to plantlets as compared to the nodal segment.

Evaluation

Mahla and Singh (2013) collected and characterized 45 collections of *kair* from Western Rajasthan (Bikaner, Nagaur, Jodhpur, Barmer and Jaisalmer districts) and found ample

variation for fruit diameter (11.42-22.63 mm), fruit weight (1.18-7.23 g), seeds per fruit (5.2-27.8) and test weight (14.6-26.9 g). Bigger fruit size, fewer seeds are the desirable traits. Selection of elite lines from the wild and uncultivated land is the only option till now.

Varietal development

There are no released varieties of *kair*. There are some promising lines identified by the institutes. The area under cultivation of *kair* is very limited and most of the produce comes from forest.

Lasoda (*Cordia myxa* Roxb.)

Cordia myxa Roxb. (Indian cherry, Lasoda, Goonda) is a large evergreen tree with a dense crown, which can grow up to 12 metres. It is a multi-purpose tree and uses include - food, medicine and source of wood, fibre, etc. It is originated in the Indian subcontinent but is also cultivated in western African countries for its edible and medicinal fruits. The fruit makes an excellent pickle (Tripathi, 2020). The ripe fruit is eaten by children despite gum-like substances when ripe. It belongs to family Boraginaceae. The other important species are *C. gharaf* (goondi), *C. rothii, C. macleodii, C. vestita* and *C. wallichii. Cordia myxa* originated in the sub-Himalayan region extending through the forests of India, Nepal and Myanmar and can be found growing up to 1,500 meters MSL. It is distributed throughout the country mainly in warmer parts of the country. It is mostly found as wild and only occasionally as cultivated. *C. myxa* found growing home gardens, backyards and farmers' fields as an isolated tree or a few in numbers. It is also found in Taiwan, Thailand, Malaysia, China, Polynesia and Australia. In India, lasora grows in moist and dry forests of Rajasthan, Punjab, Maharashtra, parts of the sub-Himalayan tract and the Western Ghats. It prefers ravines and valleys.

Genetic resources

Great variation exists in natural population with respect to morphological characters particularly plant height, spread, leaf size, fruit size; fruiting behaviour; fruit characteristics like colour, pulp content, pickling quality, seed, pulp ratio, etc. However, it has neither been systematically collected from areas of its natural distribution nor there have been any efforts to exploit it. More recently, some efforts have been made by ICAR-NBPGR Regional Station, Jodhpur and ICAR-CIAH, Bikaner to identify some big fruited types with high productivity. At CCS HAU, Hisar, different genotype was evaluated by Saini *et al.* (2002) and they reported variability in plant height and spread. High genotypic coefficient of variation and phenotypic coefficient of variation for fruit weight and leaf size together with high heritability and genetic advance has been recorded by Samadia (2007). Pulp: stone ratio had a significant positive correlation with most of the parameters except several fruits per cyme and stone thickness, and it had a negatively significant correlation with several flowers per cyme (Nagar *et al.,* 2013).

Kaushik and Dwivedi (2004) reported a wide range of diversity in morphological and quality characters in 45 collections of lasoda from Haryana. In general, two types of plants viz., large-fruited and small-fruited are found growing and are sold by local people. Large fruited cultivars have an average fruit weight of 8.55 g, whereas small-fruited cultivars have fruit weight of 3.0 g. In the case of large-fruited cultivars, fruit have comparatively more pulp thickness and therefore are suitable for consumption. Large fruited types in Gujarat also recognized as 'Paras Gonda', is a general term for any fruit variety with big size fruits. Similarly, in Rajasthan 'Puskar Local' is big with good fruit shape. At CIAH, Bikaner under *ex-situ* conservation, 65 types of lasoda have been collected and planted under field conditions to identify promising types.

Sivlingam *et al.* (2012) reported that there is much variation in fruits morphological character as well as molecular observations. The genus *Cordia* has about 250 species majority of which occurs in the New World. The other species in the genus *Cordia* are *C. gharaf* (Forsk.) Ehrenb & Asch. Syn. *C. rothii* Roem. & Schult.), *C. macleodi* Hook. F. & Thomas. and *C. Sebastian* L. Gonda exists in two forms, namely small-fruited and large-fruited types. The primary differences between them lie in the size of the fruits and leaves (Meghwal and Singh, 2016).

Collection

Genetic diversity of *Cordia* species, especially *C. myxa,* has been collected by ICAR-NBPGR from Rajasthan, Haryana, Gujarat, Madhya Pradesh, Himachal Pradesh and Uttar Pradesh and 134 accessions of various *Cordia* species have been collected. Besides, 45 accessions of elite germplasm have been collected by ICAR-NBPGR in collaboration with CCSHAU, RRS, Bawal from Rewari, Mahendragarh and Bhiwani districts of Haryana and germplasm was established at field gene bank at CCSHAU, RRS, Bawal and ICAR-NBPGR, Regional Station, Jodhpur. ICAR-NBPGR collected 57 accessions comprising of *C. myxa, C. crenata and C. rothii* from six states of India High genotypic coefficient of variation and phenotypic coefficient of variation for fruit weight and leaf size, representing sizable diversity in fruit weight, shape, size, surface feature, pulp content, seed size, weight and shape. One promising accession with bold and shiny fruits and prolific bearing was identified by local farmers near Kotputli, Rajasthan. ICAR-CAZRI,

Jodhpur collected 13 accessions during 2000-04 from different parts of Rajasthan and Gujarat and evaluated and vide variation in fruit size, shape, yield, and pulp: stone ratio (Anonymous, 2011). Saini *et al.* (2002) collected 27 promising genotypes were collected and planted in Haryana. ICAR-NBPGR, in collaboration with CCSHAU. RRS, Bawal collected 45 accessions. Germplasm was collected from Rewari, Mahendragarh and Bhiwani districts of Haryana and planted in the field gene bank at CCSHAU, RRS, Bawal and ICAR-NBPGR-RS, Jodhpur. Few collections of lasoda have been made from Karnataka at ICAR-IIHR, Bengaluru.

Conservation

Germplasm of lasoda is being conserved in the field gene banksat CCSHAU, RRS, Bawal (30); ICAR-CIAH, Bikaner (65); ICAR-NBPGR Regional Station, Jodhpur (73) and ICAR-IIHR, Bengaluru (17). Detailed studies conducted at ICAR-NBPGR showed that seeds are shed at about 25% moisture and exhibit high germinability (94%). Seeds exhibit desiccation tolerance to some extent, but appeared to be sensitive to freezing, but at a 6 - 8% moisture content, high recovery rate was observed. Based on these results, seeds of *C. myxa* (24 accessions), *C. crenata* (3), *C. obliqua* (1) and *C. rothii* (9) have been cryo-stored at ICAR-NBPGR, New Delhi (Malik *et al*, 2010).

Evaluation

Singh *et al.* (1999) identified two types of lasoda based on fruit maturity - one early type with small and turnip shaped fruits and the other late type with large spherical fruits. At ICAR-CAZRI, Jodhpur two elite genotypes i.e. CAZRIG2021 and CAZRIG2025 were identified based on fruit size, shape, yield, and pulp: stone ratio and other desirable attributes (Anonymous, 2011). Kaushik and Dwivedi (2004) recorded variability in fruit length (1.34-2.96 cm), fruit breadth (1.84-3.34 cm), fruit weight (11.6-25 g) TSS (8.5-28%) and seed weight(0.22-0.85 g). At ICAR-NBPGR a total of 24 accessions were characterized for traits such as fruit shape (ovoid to oval), fruit length (1.4-12.72 cm), fruit width (1.29-2.92 cm), fruit weight (1.12-9.82 g), pulp thickness (0.23- 0.56 cm), and seed weight (0.21-1.26 g). Among these, seven were found better in terms of large fruits, higher TSS, pulp thickness and smaller seeds. Similar studies have been reported by Bhatnagar, 2018; Bhatnagar *et al.,* 2015; Hare Krishna *et al*., 2019 and Tripathi *et al*., 2020.

Varietal development

Few elites' lines have been identified by some institutes viz. Thar Bold has been released by ICAR-CIAH, Bikaner, Maru Samrudhi by ICAR-CAZRI, Jodhpur and Karan Lasoda from SKN AU, Jobner (Rajasthan).

Phalsa (*Grewia subinaequalis* DC)

Phalsa is a shrub or small tree used in the Indian subcontinent since the Vedic period. The ripe fruits are consumed fresh or made into refreshing drink during summer. Phalsa fruit has a short shelf life suitable only for marketing locally. It is cultivated on a commercial scale mainly in the northern and the west India states of India. Phalsa is known by a different name in different Indian languages such as *dhamin*, *parusha*, and *shukri* in Hindi (Tripathi, 2009). Phalsa fruits are rich carbohydrate (6.8to 25.8%), sugar and acid (0.42 to 2.5%) and very little protein and fat. Phalsa belongs to family Malvaceae. The closest relative of phalsa is *Grewia elastica* var. *vastita,* which is generally found in small hillocks and valleys. Apart from these two species, there are around 150 species in the genus *Grewia.* The important ones are *G. glabra, G. micrococas, G. optiva, G. tilifolia,* and *G. belosa.* Phalsa is found wildly growing in UP, Rajasthan, Punjab, Haryana, Madhya Pradesh, West Bengal and parts of south India. The cultivation of phalsa is limited to a very small scale (may be around 1000in Punjab, Haryana, Rajasthan, and Gujarat and UP. Apart from India, it is cultivated in Pakistan, Nepal, Bangladesh, Laos, Sri Lanka, Thailand, the Philippines, Vietnam and on experimental basis in some provinces of the United States of America.

Genetic resources

There are local varieties grown in different growing regions. In Hisar area of Haryana, two local varieties i.e., tall and short are grown. The dwarf variety is more productive than the tall one. The dwarf variety has higher total sugars and non–reducing sugars that the tall variety which also has more reducing sugars. In Kanpur area two varieties namely, Local and Sharbati are grown. Not much variability is reported in phalsa due to the self-pollination. Some species belonging to genus *Grewia* are *G. asiatica* L., *G. damine* Gaertn., *G. elastica* Royle, *G. glabra* Blume, *G. helicterifolia* Wall., *Grewia microcos* L., *G. optiva* J. R. Drumm. ex Burret, *G. sapida* Roxb., *G. tenax* (Forssk.) Fiori and *G. villosa* Willd.

G. tenax is highly drought resistant and occurs in the driest savannas at desert margins and regions of higher rainfall, where it grows in thickets on termite mounds in otherwise seasonally flooded country. *G. tenax* is available in all seasons in semi desert areas and has potential as forage sources for honeybee and some other insects (Sharma and Patni, 2012). Other species which are found in drier parts of tropical Africa are *G. flavescens, G. villosa, G. bocolour, G. ferruginea, G. louisii, G. monticola, G. plagiophylla, G. pinnatifida* and *G. microthyrsa*. These may be a source of drought resistance.

Collection

Phalsa germplasm has been collected from various parts of India such as Rajasthan, Haryana, Gujarat, Maharashtra and Andhra Pradesh, by ICAR-NBPGR, New Delhi; CCSHAU, Hisar; CCSHAU, RRS, Bawal and ICAR-CIAH, Bikaner. Thirty-six accessions belonging to 6 economically important species namely *G. hirsute*, *G. oppositifolia*, *G. tiliaefolia*, *G. rothii, G. orantalis* and *G. subinaequalis* have been collected at CCSHAU, RRS, Bawal. Sivraj and Pandravada (1997) reported seventy-eight accessions of phalsa (*Grewia asiatica* L.) were collected from parts of Andhra Pradesh. Considerable variability in fruit and plant morphological characteristics is recorded. Ranga Reddy, Mahbubnagar and Medak districts have a larger area under phalsa in comparison to other areas. Few promising lines for various traits were also collected.

Conservation

Phalsa germplasm is being conserved in the field gene bank at CCSHAU. RRS, Bawal (31), ICAR-CIAH, Bikaner (6), ICAR-CIAH, CHES, Godhra (2) and IIHR, Bengaluru (1). Basic studies on seed physiology and storage undertaken at ICAR-NBPGR, New Delhi indicate that seed viability is lost after 90-100 days of storage (Chandra *et al.*, 1994). It was also found that seeds showed 50% viability after 4 months of storage at ambient conditions. Seeds were desiccation sensitive as at critical moisture content showed a 23% loss in viability. Intermediate seed storage behaviour has been concluded as seeds survived LN exposure with 500/0 viability. A total of 15 accessions of *Grewia* species have been cryo-stored in the cryogene bank (Malik *et al.,* 2010)

Evaluation

There are local regional favourites land races grown in different regions. Some growers have given names like'Local' and 'Sharbati' to different phalsa types (Dhawan *et al.*, 1993). Two distinct types, i.e., Tall and Dwarf were recognized at Haryana Agriculture University, Hisar. These two types differ in their plant height, fruit yield and other morphological parameters such as leaf size, fruit size and fruit weight. These two types did not show any marked variation in their fruit weight, edible portion, seed weight and juice yield. The tall type had a higher content of reducing sugars whereas total and non-reducing sugars were higher in dwarf type. However, glucose was observed only in the tall type (Dhawan *et al.*, 1993).

Varietal development

Most of the genotypes grown are of local types. Some promising one like 'Thar Pragati 'has been identified for cultivation by ICAR-CIAH, Bikaner.

Tamarind (*Tamarindus indica* L.)

Tamarind belongs to the family Fabaceae. It is one of the most widespread trees of the Indian subcontinent. It is a large evergreen tree with an exceptionally beautiful spreading crown and cultivated throughout the India, except in the Himalayas and western dry tracts. Tamarind is a multipurpose plant. The pulp of the fruit has been used as a spice in India, especially in the southern part of India, for a long time. Almost all parts of the tree are used in the food, chemical, pharmaceutical or textile industries, or as fodder, timber and fuel. It is grown throughout India and vast diversity is available in the states of Maharashtra, Andhra Pradesh, Chhattisgarh, Tamil Nadu, Gujarat, Rajasthan and the north-eastern states and naturalized in several regions. In the American continent, commercial plantations were reported in Belize, Central American countries and in northeast Brazil (Sharma and Bharadwaj, 1997). Although it is grown in many countries, tamarind is grown as a plantation only in a few countries such as India and Thailand.

Genetic resources

Tamarind is a semi-domesticated species, and has long been planted in many areas in tropics. In Indian subcontinent is present both in wild and cultivated areas, and the later, although ill-defined, could be considered as landraces. There is large variability in morphological and fruiting characters. The selection from the land races has resulted in the identification of distinct varieties varying in the taste of the pulp (sour, sweet, or bitter) and size of the pod (long or short).

Diallo *et al.* (2007) defined that there are three major groups of tamarind populations in West Africa, East Africa, and Cameroon. They have also demonstrated that, although self-pollination is common in tamarind, most often there is pre-zygotic self-incompatibility and cross-pollination is common leading to expression of high genetic variability. Tamarind is a monogenic species so there are no possibilities of out crossing with other species. There are several types of tamarind available in the forest and uncultivated areas. Being a cross-pollinated crop, large viability in the wild population has been reported from India and African countries. The large variation in tree growth, canopy size, flowering pattern, fruit productivity, pulp colour and sweetness exist in tamarind. Based on the pulp colour tamarind has been delineated as red tamarind and brown tamarind.

Collection

Systematic collections and evaluation of tamarind germplasm from India have not been taken up. However, 248 samples were collected by various organizations mainly from the states of Bihar, Jharkhand. Gujarat, Tamil Nadu,

Andhra Pradesh, Madhya Pradesh, Kerala, Karnataka, West Bengal and north-eastern states. The attention has-been given to this crop under-the ICAR network project on underutilized fruits and some promising collections have been made by ICAR-CISH, Lucknow (5 accessions) and CHES (CIAH), Godhra from Uttar Pradesh, Madhya Pradesh and Gujarat.

Variability of tamarind has also been collected from Maharashtra, Karnataka, Andhra Pradesh and Chhattisgarh by State Agricultural Universities and State Forest Departments. ICAR-NBPGR, New Delhi collected 9 diverse germplasm collections from various states. The wide variation is recorded in the species due to its out crossing ability. ICAR-IIHR, Bengaluru, more than 100 collections were made from Karnataka, Maharashtra, Chhattisgarh, Odisha, Jharkhand, Assam, Tamil Nadu and some sweet types have been identified and collected (Kanupriya, 2023).

Conservation

Germplasm of Tamarind is being maintained at several state Agricultural Universities and state forest departments viz. UAS, Dharwad (19 accessions), Marathwada Agricultural University, Parbhani (3), Aurangabad, Maharashtra (351), Pune, Maharashtra (118), Horticulture College and Research Institute, Periyakulam, Tamil Nadu (85), TNAU, Research Station, Tupukotti (26), ANGARU, Research Station, Anantapur (15), ICAR-CIAH, CHES, Godhra, ICAR-IIHR, Bengaluru (>100) and Belgaum, Karnataka (40). Besides, several promising accessions are being conserved by the Forest Department, Karnataka (220 plus trees), and Forest Department, Tamil Nadu (328 plus trees).

Lot of collections of tamarind genotypes have been made throughout the tropics. There is an estimate that there are 19327 genotypes worldwide. Studies on seed physiology, storage behaviour and cryopreservation of tamarind seeds have been undertaken at ICAR-NBPGR, New Delhi. Seeds are orthodox as they showed complete desiccation and freezing sensitivity and seeds showed up to 50% viability by 18 months storage. Freshly shed seeds showed 35% moisture with high viability of 97%. Seeds retrieved from liquid nitrogen showed high viability of 94%. Total 10 accessions of tamarind have been cryo-stored at ICAR-NBPGR, New Delhi (Malik *et al*, 2010).

Evaluation

Considerable variation in tree growth, canopy size, flowering pattern, fruit productivity, pulp colour and sweetness exist in tamarind. Based on the pulp colour tamarind has been classified as red tamarind and brown tamarind. The red pulp colour in unripe fruits is due to the presence of anthocyanin in cell vacuoles which is a natural water-soluble, non-toxic pigment and there is considerable potential of red tamarind as a bio colourant in food processing. Ten tamarind accessions were evaluated at TNAU, Research Station, Arupukottai. Reproductive biology and breeding system have been studied in 5 clones of tamarind at IFGTB, Coimbatore. Variability in morphological and physicochemical characters has been observed in the germplasm collected from Maharashtra (Keskar *et al*., 1989), Karnataka, Andhra Pradesh (Mastan *et al*., 1997) and Chhattisgarh. State Silvicultural Division, Tirupati (AP) identified 52 high yielding genotypes of tamarind based on morphological and physicochemical characters of fruits. A red-fleshed tamarind tree having sweet pulp (TSS>85%) have been reported in village Faraskot, Dantewada, Bastar district of Chhattisgarh.

Germplasm collected at ICAR-NBPGR, New Delhi have been characterised for some fruit and seed characters. The fruit length x width varied from 7.50 cm x 1.76 cm to 11.13 cm x 5.94 cm. The total fruit weight showed variation ranging from 6.4 to 12.93 g. Seed length x width varied from 0.93 cm x 1.02 cm to 1.43 cm x 2.20 cm. The seed weight ranged from 0.5 to 0.76 g. Mayavel *et al.* (2018) evaluated 21 genotypes of red tamarind collected from different parts of Tamil Nadu, Puducherry, Karnataka and Andhra Pradesh. The wide variation was recorded for length of inflorescence (13.32 cm and 5.20 cm), number of flowers/ inflorescence (27.15 and 10.86), yield/ tree (40.26 kg and 14.56 kg), fruit length (12.02 cm and 4.96 cm), fruit breadth (3.15 cm and 1.32 cm), fruit weight (13.94 g and 4.89 g), pulp weight (7.99 g and 2.50 g), number of seeds (8.10 and 3.92), seed weight (7.86 g and 1.93 g) and anthocyanin content (246.94 mg/L and 123.06 mg/L).

Agasimani *et al*. (2019) assessed thirty-one tamarind genotypes in six districts (Belagavi, Dharwad, Gadag, Bellary, Chitradurga and Gulbarga). A high degree of variation was observed for tree height, trunk diameter, the spread of the tree east to west, the spread of the tree north to south, crown size, pod length, pod thickness, pod weight, pulp weight, number of seeds per pod, seed weight per pod, shell weight per pod, vein weight per pod, pulp per cent, seed per cent, shell per cent, vein per cent, tamarind pod yield and tartaric acid content.

Varietal development

Several varieties have been developed through selection from germplasm collected across different states. Fruit Research Station, Aurangabad of Marathwada Agricultural University, Parbhani, Maharashtra released three varieties of tamarind namely Pratisthan, Yogeshwari and Selection No.263. PKM-l was released from Horticulture College and Research Institute, Periyakulam. Urigam- 1 was released by Department of Horticulture, Tamil Nadu. Two selec-

tions DTS 1 and DTS 2 have been identified by College of Horticulture, Arbhavi, Dharwad. ICAR-CIAH-CHES, Vejalpur also identified promising genotype Goma Prateek and Thar Rashmi and FRS, Ananathapuram also released Anantha Rudhira & Thettu Amblika. PDKV, Akola (MS) also released variety as Akola Smruti (AKT-10) and farmer's variety Lakshmana identified for release from ICAR-IIHR, Bangaluru. Makham Waan, Secthong, Tamarind sweet types are varieties from Thailand.

Aonla (*Emblica officinalis*)

The Indian gooseberry (*Emblica officinalis*), commonly known as aonla, is a valuable minor fruit crop native to India. It thrives in a wide range of soil types and climatic conditions across the country. Extensive research over the past two decades has led to the development of more than 30 improved varieties, allowing for commercial cultivation in several regions. Aonla has demonstrated its adaptability to arid and semi-arid ecosystems, where it proves to be a hardy, highly productive, and economically viable fruit crop, even under drought-prone and saline conditions. However, due to its highly acidic and astringent taste, fresh consumption is limited. Aonla is sensitivity to frost in cold climates, especially in hot arid regions.

Genetic resources

In India, the natural distribution of wild aonla is found on the Himalayas, Chota Nagpur, Bihar, Orissa, West Bengal, North Circars, Deccan, Karnataka and in Western Ghats (Rawat and Uniyal 2003). It has been naturalized in great profusion in North Eastern India. The genus *Phyllanthus* comprises about 350 or even 500 species; mostly shrubs, few herbs and trees. *Phyllanthus emblica* Linn. has now been placed under *Emblica officinalis* Gaertn. Of the related species *Phyllanthus acidus* Skeel., syn. *P. distichus* Muella, popularly known as otaheite gooseberry, star gooseberry or country gooseberry, is mostly grown for ornamental purpose, whereas wild species *Emblica fischerry* Gamble., syn. *P. fischerry* found in the forest of south India, bears fruits suitable for pickle making (Srivastava *et al*., 1997).

In western and eastern Ghats, three species namely *Phyllanthus emblica*, *P. indofisheri* and *P. acidus*are of common occurrence. The wild aonla germplasm is mostly confined in the mixed forests with sloppy topography and sometimes even difficult to approach. A rich genetic diversity of aonla exists in north-eastern region of India, particularly in lower Assam, Maghalaya (Khasi and Garo hills), Mizoram and Tripura. The natural population of aonla in west Khasi hills (Nongkhyllum, Rajaju, Khonjoy area) of Meghalaya warrants *in-situ* conservation, which may even be declared as gene sanctuary for this species (Pathak, 2003). Mizoram (forests of Kolasib, Thingdawl and Champhai), the homeland of wild aonla and star gooseberry (*Phyllanthus acidus*), which has potential as dwarfing rootstock for aonla. Madhya Pradesh forests also have rich diversity of aonla in Sheopur, Betul, Balaghat, Satna, Sidhi, and Panna districts.

The important sites in Jharkhand are Lali Forest near Ranchi, Dalma range of Jamshedpur, Theo Ghat Forest of West Singhbhoom, Tiamara valley area between Ranchi and Jamshedpur, Ramgarh area of Hazaribagh, Parasnath hills of Girideeh, Kodemera and Jaomi areas of Bihar border, Simdega and Netarhat forest areas of Gumla, Belta forest of Daltonganj, Palamu and Garhwa of Jharkhand and adjoining areas of Sarguja and Ambikapur districts of Chhatisgarh. The Belta forest (Daltonganj), Netarhat range in Gumla and Dalma range of Jamshedpur has comparatively high plant population of aonla in the natural habitat. A wild strain of aonla grows in the Himalayas up to an altitude of 1600 msl even at places which experience mild snowfall during winter months, displaying cold tolerance.

Collection

Wide variability in aonla has been reported from Uttar Pradesh, Uttarakhand, Bihar, Chhattisgarh, Gujarat, Jharkhand, Madhya Pradesh, Maharashtra, Rajasthan, Himachal Pradesh and North Eastern region of India (Singh *et al.*, 2016). An extensive survey was made to identify and collect the elite genotypes at different altitude to determine variability for physical and biochemical traits and find out the promising genotypes having good fruit quality from different regions of the north-eastern region of India, i.e. Manipur, Meghalaya, Asom and Nagaland (Singh *et al.*, 2016). In Uttar Pradesh, its cultivation is more common in Pratapgarh, Varanasi, Sultanpur, Azamgarh, Jaunpur, Rai Bareilly, Agra and Bareilly. Of which, Pratapgarh is a leading district of aonla cultivation on commercial scale throughout the country (Pathak *et al.*, 1993).

Aonla cultivars were characterized and evaluated using aonla descriptors developed at ANDUA&T, Ayodhya that revealed a broad range of variability for different characters. Four promising accessions were identified characterized 33 genotypes of aonla collected from Uttar Pradesh (Rai *et al.*, 1993) based on the horticultural traits. Singh *et al.* (2016a) surveyed the north east states viz., Meghalaya, Manipur and Nagaland and identified three elite genotypes based on the desirable horticultural traits. Owing to predominance of seedling propagation, India holds rich genetic diversity in cultivated and their wild relatives of aonla.

Genetic erosion status of these resources is constantly high due to severe deforestation, urbanization, natural calamities and adoption of a few popular cultivars in the selected pockets. However, enormous variability in aonla still

remains unexploited and awaits proper attention on exploration, collection and maintenance to conserve genetic diversity available in the nature. The desirable traits for germplasm collection include large fruit size, low fiber content, and resistance to frost, rust, internal fruit necrosis and insect-pests. Many of the present-day varieties have been developed from these collections as chance seedlings of these genotypes.

Conservation

Currently the genetic diversity of aonla is conserved by *ex-situ* in field gene banks of ICAR institutes and State agricultural universities (Table 3). *Ex-situ* and *in-situ* conservation strategies require a large area, a huge effort for maintenance. Therefore, biotechnological approaches such as *in-vitro* conservation and cryogenic storage (-196°C liquid nitrogen) can help for long term storage of germplasms.

Table 3. Status of national germplasm banks of aonla

ICAR Institute/ SAU	Accessions
ANDUA&T, Ayodhya	22
ANGARAU RRS, Anathapuram	15
ICAR-CIAH, CHES, Godhra, Gujarat	18
TNAU RRS, Aruppukottai	15
ICAR-CISH, Lucknow	12
ICAR-IIHR, Bengaluru	12
SDAU, SK Nagar	12
MPKV, Rahuri	8
CCS HAU RRS, Bawal	6

Characterization and evaluation

Assessing genetic variability for varietal enhancement necessitates a comprehensive capture of both quantifiable and non-quantifiable morphological characteristics. The Aonla germplasm showcases notable variability in morphological traits, growth, flower, bark, and fruit characteristics, reflecting the diversity across its tree (Singh *et al.*, 2024). The characterization of aonla germplasm for tree, foliage, fruit and stone attributes under semi-arid ecosystem of Haryana (Singh *et al.*, 2022). Among the 11 genotypes characterized, CISH-A-33 and CISH-A-31 exhibited superior fruit yield per plant (Pandey *et al.*, 2025).

The cultivars of aonla, viz. Banarasi, Chakaiya, Neelam, Francis, Kanchan and Desi were evaluated for growth, yield and quality parameters under lower Shivalik foothills of Himalayas. Neelam cultivar of aonla is most superior under the rainfed conditions (Bakshi *et al.*, 2015). The variety Krishna was found superior compared to other varieties for fruit characters and ascorbic acid content under Bengaluru Conditions (Chiranjeevi *et al.*, 2015). Tripathi *et al.* (2016) found that the fruit yield was highest in cv. Chakaiya (26.78 kg/ plant) and cv. Krishna (26.34 kg) under humid tropical conditions of Chettalli (Karnataka). Rozar *et al.* (2024) evaluated 84 wild aonla genotypes for morphological, physical, and biochemical characteristics from Mizoram, Meghalaya, and Tripura states of Northeastern India.

Varietal development

Three varieties of aonla viz Chakaiya, Francis and Banarsi were popular before 1980. Later on, several varieties of aonla have been developed through selection. These includes NA-4 (Krishna), NA-5 (Kanchan), NA-6 (Amrit), NA-7 (Neelum), NA-9, and NA-10 (Balwant) from ANDUA&T, Ayodhya, as well as Anand Aonla-1 from AAU, Anand, Aonla-2 from ICAR-CISH, Lucknow, Goma Aishwariya from ICAR-CIAH, CHES, Godhra, BSR-1 (Bavanisagar) from TNAU, Coimbatore. These varieties are high yielding with bigger size fruits.

Dragon fruit (*Hylocereus* spp.)

Dragon fruit (*Hylocereus undatus*), also known as the Kamalam, "Wondrous Fruit" of the 21st century or strawberry pear belongs to the cactus family (Cactaceae). It originates from Central and South America, particularly in countries like Mexico, Guatemala, Nicaragua, Costa Rica, and El Salvador. Over time, it has successfully adapted to various tropical and subtropical regions, including Southeast Asia, India, and Africa. This fruit comes from the *Hylocereus* genus, which consists of around 14 species of climbing cacti. Closely related to *Selenicereus* and *Epiphyllum*, these plants share characteristics such as growing on trees or rocks, blooming at night with large, fragrant flowers, and producing fleshy fruits filled with tiny seeds. The main cultivated varieties include *Hylocereus undatus* (white-fleshed), *Hylocereus costaricensis* (red-fleshed), and *Selenicereus megalanthus* (yellow). It has successfully spread to various tropical and subtropical regions worldwide, including Southeast Asia, the Indian subcontinent, and parts of Africa and has emerged as a fruit of significant global interest in recent years. In recent years, the cultivation of dragon fruit has expanded significantly, driven by increasing demand in both local and international markets. It is a hub for many underutilized horticultural crops which may not know to other parts of the country. Most of the lands in this region is virgin and remain unexploited which may be used up for cultivation of different crops which are emerging lately in these areas.

Genetic resources

Pitaya (Dragon-fruit) originated from Latin America. Since the early 1990s, when introduced to China, it has been widely cultivated in China and has become economically important fruit crop. The majority of germplasm accessions are white or red pulp types. The estimations of genetic diversity and relationships are important for evaluating, conserving and utilizing plant resources and for

determining uniqueness and distinctness of genotypes. Traditionally, the methods for pitaya cultivar identification have based on morphological traits. Variation in chromosome number (polyploidy), is considered a significant phylogenetic feature in the evolution of the *Cactaceae* family (Cota and Philbrick 1994). Cytogenetic research revealed that the chromosome number in the *Cactaceae* family has a base number of n = 11 (Gibson and Nobel 1986).

Within the genus *Hylocereus*, including species such as *S.undatus, S. monacanthus, and S. costaricensis*, they are diploid (2n = 2x = 22), whereas *S. megalanthus*is allotetraploid (2n = 4x = 44), due to natural hybridization (Lichtenzveig *et al*., 2000; Tel-Zur *et al.,* 2005). The basic chromosome number is x = 11 for both diploids and tetraploids (Ross, 1981). In a study by Tel- Zur *et al*. (2003), chromosome doubling was induced in vine cacti hybrids through reciprocal crosses between *S. megalanthus* (4x) and *Selenicereus* spp., specifically *S. undatus and S. monacanthus.* Surprisingly, viable hexaploids and 6x-aneuploid hybrids were obtained instead of the expected triploids when crossing *S. megalanthus* with *S. undatus*. The uniform pollen grain diameter of *H. undatus* indicated a low frequency of unreduced gametes, whereas *S. megalanthus* pollen exhibited variation, suggesting the occurrence of unreduced gametes.

Collection

In India currently there are 56 germplasm collections in ICAR-IIHR, Hirehalli, out of which 36 are exotic. Some of the dragon fruit germplasm collections are listed below in Table 4 (Yadav *et al*., 2025).

Table 4. Dragon fruit germplasm maintained at different centres

Institute	Accessions
ICAR-IIHR, CHES, Chettalli	04
ICAR-IIHR, CHES, Hirehalli, Tumakuru, Karnataka	56
ICAR-IIHR, CHES, Bhubaneswar	03

Conservation

Breeders and farmers need access to the wildest possible pool of genetic resources, either collected from the wild or from the farmers. Gene bank plays an important role because they can act as a centralized storage facility of diversity. In Belgium they have successfully developed *in-vitro* cultured plant material by help of sterile stock provided by Botanical Garden. The materials were being maintained in plant growth room at 26°C under 16/8h light/ dark regime. Then have executed *in-vitro* initiation for long term conservation via cryopreservation. Cactaceae family initial study for post-cryopreservation regeneration rates resulted between 0 and 90%. Dragon fruit seeds were being stored at room temperature, in refrigerator at 7°C and freezer at -20°C which resulted in >90% germination rate (Wilms and Panis, 2023).

Evaluation

About 18 species in the genus Hylocereus were found in West Indies, Mexico, Central America and northern South America evaluation of Hylocereus genus led to the conclusion that most of the species were having 3-angled stems with 2 to 6 brown coloured spines seated on the areoles which were 2 to 6 cm apart on the vines. Rahmawati and Mahajoeno (2009) reported a study of variations of dragon fruit based on morphology, isozyme, and vitamin C content in the area of Pasuruan (East Java), Sukoharjo, and Klaten (Central Java), and Bantul sub-districts (Yogyakarta). Tran *et al*. (2015) reported a study on pollination methods on fruit set and fruit characters in several Pitaya clones, which aimed to improve pollination efficiency, fruit quality, and yield by determining pollination agro-management requirements.

The species *H. polyrhizus* and *H. costaricensis* were differentiated based on their stem and fruit characters, even though both the species had a pink skin. Tran *et al*. (2015) evaluated 30 dragon fruit germplasm in which Damao 9, D 4, D 13 observed better fruiting and flowering quality. Rifat *et al*. (2019) evaluated variability of 15 genotypes of dragon fruit which were collected from Thailand and Vietnam. Sarker *et al*. (2022) evaluated 3 different germplasm collected from Bangladesh and found 2 genotypes produced excellent quality fruits and other genotype was said to need further testing. Sethunath and Bhaskar (2024) evaluated the variability among the dragon fruit (*Hylocereus* spp.) genotypes in 4 different districts of Kerala.

Varietal development

There are three major types' viz. red colour fruit with white colour flesh, red colour fruit with red colour flesh and yellow colour fruit with white colour flesh. The systematic work of dragon fruit improvement was initiated at ICAR- IIHR, Bengaluru. Four varieties *viz.*, CHESH-D1, CHESH-D2, CHESH-D3, CHESH-DE (mutant) were identified (Karunakaran *et al*., 2024).

Jamun (*Syzygium cumini*)

Jamun (*Syzygium cuminii* Skeels) belongs to the family Myrtaceae. It is native to Indian subcontinent and has grown naturally since time immemorial. Itis found in all parts of our subcontinent as well as countries of Southeast Asia and Eastern Africa. In India, it is grown widely all over the country except higher hills. The most commonly found variety of jamun is often oblong and has a deep purple to bluish colour. The pulp of the fruit is grey or pink and has a seed in the centre. The fruit is acidic and astringent in

nature, with a sweet taste. Lot of variation exists in respect of growth and fruit characters.

Genetic resources

As majority of jamun trees are of seedling origin, and they show tremendous variation in their morphology and physico-chemical attributes. The extent of variability increases when this highly cross-pollinated plant multiplied through seed. Singh and Singh (2012) assessed the variability in terms of flowering, fruiting and fruit traits under Gujarat conditions. Regional Fruit Research Station, Ventura, Maharashtra maintains a rich germplam and one promising germplasm has been released in the name as "Konkan Bahadoli" which is having bold fruits, small seeds, heavy and cluster bearing habit (Salvi, 2006). Still, many types differing in economic traits need to be surveyed, collected and maintained. Genotypes with extended fruiting period have to be identified as a priority one as this fruit is now available only for very limited weeks in nature.

Seedless Jamun is also available at TNAU and IIHR (Tripathi *et al*., 2020) but its limitations are small in size and instability in selflessness due to its chimer nature. Diversity exists in respect of vegetative growth, aspects of spread, leaf shape and fruiting habit and maturity (June - August). However, very little work has been carried out to understand and exploit the genetic resources of jamun. The crop is facing severe threat of genetic erosion as a result of urbanization and intensive agriculture. The genetic diversity of the related wild *Syzygium* spp. is of particular value in search for sources of resistance to races/pathotypes of fungi, bacteria, viruses and nematodes besides winter hardiness and resistance to drought and salinity.

Table 5. Jamun collections maintained at different centres

Name of center	Source	Total collection
ICAR-CISH, Lucknow	Uttar Pradesh, Bihar, Haryana, Gujarat, Maharashtra, Tamil Nadu and Karnataka	40
ICAR-IIHR, CHES, Chettalli	Uttar Pradesh, Haryana, Gujarat, Tamil Nadu and Karnataka	30
ICAR-CIAH, CHES, Godhra	Uttar Pradesh, Bihar, Haryana, Gujarat, Tamil Nadu and Karnataka	50
ICAR-IIHR, Bengaluru	Uttar Pradesh,Bihar, Madhya Pradesh, Assam, Gujarat, Tamil Nadu and Karnataka	110

Collection

In India, there are several types of Jamun. The small-fruited type large-fruited type, seedless type, purple coloured, white coloured etc. Jamun germplasm is collected and conserved by ANDUA&T, Ayodhya; GBPUA&T, Pantnagar; ICAR-CISH, Lucknow; ICAR-CIAH, Bikaner; ICAR-CAZRI, Jodhpur; ICAR-NBPGR-Regional Station, Jodhpur; ICAR-IIHR, Bengaluru. The collections from Bihar, Jharkhand are conserved at ICAR-NBPGR-RS, Jharkhand (Dhakar *et al*., 2019). ICAR-IIHR, Bengaluru explored Karnataka, Andhra Pradesh, Telangana and collected more than 100 accessions (Tripathi *et al.*, 2017). The Jamun germplasm is also collected at several other research stations. There may be many duplicates in the germplasm at different stations, as many samples were collected from secondary sources. The available jamun accessions are conserved at the field gene banks as given in Table 5.

Conservation

Jamun germplasm is conserved using *in-situ* and *ex-situ* approaches. The seed of Jamun are recalcitrant type and polyembryonic and cannot be stored for long time. Being native to India, work on collection and evaluation is mainly confined to India, with a few studies reported from Sri Lanka, Pakistan, Bangladesh and South Eastern Asian countries.

Evaluation

A number of seedling strains with considerable variation available in respect of fruit shape, size, pulp colour, TSS, acidity and earliness particularly in Uttar Pradesh, Gujarat and Maharashtra, can offer good scope for selection of better varieties. It has been noted that F_1 hybrid from a cross between the Alba variety of water apple *(S. javanicum)* and rose apple *(S. jambos)* had prolific bearing with larger fruits than those of the parents. The fruits contained the fragrance and sweetness of rose apple. The majority of jamun trees available in India are of seedling origin. Owing to cross-pollination and seed propagation, there is enormous variability in respect of fruit morphology, fruit quality, maturity, and productivity. Explorations carried out, particularly in the eastern Uttar Pradesh, indicated considerable variability in respect of fruit shape (round, oval, oblong, perform), fruit base (flat, necked), fruit apex (flat, pointed), skin colour (deep purple, purple-pink, bluish-black, black), flesh colour (purple, purple-pink, white), fruit weight (5.77 - 19.73 g), fruit length (2.06-3.81cm), fruit diameter (1.94-2.98 cm), seed weight (0.141- 1.94 g), seed length (1.6-2.4 cm), seed diameter (0.8–1.3cm), pulp content (54.29–85.71%), TSS (4.5-17°Brix), acidity (0.524 - 0.832 %), pulp: seed ratio (3.03 - 46.38), moisture (84.5 - 86.4 %), total sugars (5.32 - 11.10 %) which need to be characterized for utilization in crop improvement.

Ashraf *et al.* (1987) reported that fruit shape varied from round to oblong and apex of fruits from flat to pointed.

They also observed great variability in physico-chemical characteristics, offering the possibility of selecting varieties suitable for fresh market and processing. Small seed size and high pulp content with better chemical parameters are considered ideal. Singh *et al.* (1999) evaluated eight accessions of jamun under Faizabad conditions and reported that oblong types had more fruit weight with relatively lesser seed weight. Among the locally available types in West Bengal, Selection No. 1 (oval shaped large fruit) and Selection No. 2 (cylindrical shaped medium sized fruit) proved better on the basis of yield and fruit quality attributes.

A survey in north Goa indicated a wide range variation in fruit weight (3.42-13.67 g), length (3.31-5.26 cm), girth (5.21-9.82 cm), pulp (58.57-84.55%), TSS (12.00-26.8°Brix), titratable acidity (0.59-1.63 %), total sugars (6.87-25.31 %) and sugar: acid ratio (15.39-27.92). Rekha *et al.* (2020) studied variation in the degree of polyembryony among the jamun accessions collected from different states. The collections of Jharkhand were found to produce higher number of single seedlings; whereas collections from Dharwad region are highly polyembryonic producing highest numbers of multiple seedlings. In another study, the morphological variability of 21 distinct jamun genotypes sourced from Bangalore Rural, Shivamogga, and Chikmagaluru districts in Karnataka were evaluated for 19 quantitative and 15 qualitative characteristics. The study highlighted the pivotal attribute of pulp percentage, ranging from 44.8% to 100%, with seedless varieties, specifically J13, J14, and J16, exhibiting the highest pulp percentage, and J18 the lowest.

Additionally, the entire fruit weight, varied widely from 0.74 g (J14) to 15.41 g (J4) and the revealed positive relationships between pulp weight and attributes like leaf length, tree spread, and seed width, while a negative correlation was observed with total soluble solids (Tripathi *et al.*, 2025). Sane *et al.* (2025) have reviewed the jamun diversity and its sustainable utilization. Jamun germplasm has been widely collected from different agroecological regions of India and is being maintained at government-funded institutes and agriculture universities across India. An intensive survey for utilization of the diversity available in jamun has resulted in a few promising high-yielding varieties. Nevertheless, a comprehensive and integrated taxonomical, morphological, biochemical, and molecular study will help in identifying actual diversity for better genetic resource management of this potential fruit crop (Sane *et al.*, 2025).

Varieties

Most of the jamun plantations are seedling trees. Some few superior varieties and lines have been identified for commercial orcharding namely Kokan Bahadoli from BSSKVV, Dapoli, Goma Priyanka and Thar Kranti from ICAR-CIAH, CHES, Godhra, Narendra Jamun-6 from NDAUT, Ayodhya, Rajendra Jamun -1 from Bihar Agriculture College, Bihar, CISH J-37 (Jamwant) and CISH J-42 from ICAR-CISH, Lucknow.

Mahua *(Madhuca longifolia* var. *latifolia/ Bassia latifolia)*

Mahua is an economically multipurpose tree. It belongs to the family Sapotaceae. The flowers, fruits, seeds and oil are used for various products. The flowers are a rich source of sugar and are used for the preparation of distilled liquor. Fruits are eaten raw or cooked. The fruit pulp can be used as a source of sugar for alcoholic fermentation. Seeds are a good source of oil. Mahua trees are found in almost all parts of India but commonly grow in eastern Uttar Pradesh, Madhya Pradesh, Chhattisgarh, Maharashtra, Bihar, Jharkhand, Odisha, Andhra Pradesh, and Gujarat. The exact data on area and production of this fruit in India are not available. The production is mainly concentrated in the drier states and the produce is collected by the villagers and sold in the local market.

Genetic diversity

It is highly heterozygous, cross-pollinated fruit crop and as such seedlings exhibit a wide range of variations, which aids in the selection of the superior desirable genotypes. Due to cross pollination and predomination of seed propagation over a large period of time, it gives immense opportunity to locate elite trees having horticultural traits. A wide range of variability was observed in sweetness, acidity, size, shape and bearing habits in Mahua under Uttar Pradesh conditions (Singh *et al.*, 1999). Yadav *et al.* (2011) observed the variability in oil content and seed weight of 37 accessions of *mahua*. *Mahua* collected from different parts of Tamil Nadu, India, were assessed for seed weight and oil parameters, namely, kernel oil percent, palmitic acid, stearic acid, oleic acid, and linoleic acid. Maximum seed weight (340 g) was recorded in IC554535, and the least weight (100 g) was recorded in IC554545. Kernel oil ranged from a minimum of 44.4% in IC554535 to a maximum of 61.5% in IC556617.

Collection

Survey and collection of mahua germplasm have been carried out done almost all *Mahua* growing areas. Suryawanshi and Mokat (2020) collected 99 accessions of Mahua from the North Western Ghats for morphological and sugar analysis of flowers. It was revealed that accession ML01 has the highest amount of sugar (70.29 %) content compared to other accessions. Accession ML57 showed the highest amount of 100 flower weight. Twenty-four promising

accessions have been identified, collected, multiplied and established in field gene bank for evaluation of growth and fruiting pattern at ICAR-CISH, Lucknow.

Conservation

Germplasm collection has been carried out by many institutes, and maintained at different institutes. A total of 272 mahua germplasm accessions are being maintained at different centers across India. The highest number of accessions (86) are conserved at CCS HAU, Hisar, followed by TFRI, Jabalpur and ICAR-NBPGR, Thrissur with 53 accessions each. ICAR-CIAH, Bikaner maintains 50 accessions, while ICAR-CISH, Lucknow holds 30 accessions.

Evaluation

A total of 99 accessions were collected for the morphological and sugar analysis of flowers. From the study, it was revealed that accession ML01 has the highest amount of sugar (70.29%) content compared to other accessions. Accession ML57 showed the highest amount of 100 flower weight. Singh *et al.* (2005) surveyed Panchmahal and adjoining areas to identify the elite genotypes of mahua. It was found that there was a wide variation among the genotypes for flowering time and yield. Peak period of flowering was earliest, in the first week of March. Dry flower yield ranged from 27-48 kg/plant being highest in MH 32. Fruit yield was found to be highest in MH 32 (98.00 kg/plant). The flower Juice was found to be highest (67.00 %) in MH 32. Total soluble solids, total sugar, reducing sugar, and vitamin C content of flowers were the highest in MH 32. The weight of the mahua fruit was found to be maximum in MH 34. The seed per cent was found to be maximum in MH 35 (42.91). The total soluble solids, total sugar, and vitamin C contents of the fruits were maximum in MH 32. The kernel percent varied from 74.13-82.68, with the highest in MH 24. The highest protein and mineral contents were recorded in MH 34. Fruit yield was found to be positively and significantly associated with flowers and fruits per fascicle, flower weight, and flower yield per plant.

For all traits studied in these genotypes, MH 32, MH 34, MH 35, MH 26, MH 27, MH 23, and MH 33 were found to be promising and would be exploited as potential parents to develop high-yielding stable genotypes.Twenty-four promising accessions were evaluated for growth and fruiting pattern at ICAR-CISH, Lucknow. The range of different parameters was flower weight (1.10 to 2.63 g), flower length (1.53 to 2.60 cm), diameter (1.46 to 1.90 cm), and TSS (14.53 to 26.0°B). The juice content in the accessions variedfrom 44.25 to 64.90%, and a few superior types were identified (Singh *et al.,* 2012).

Varietal development

Few elite lines have been developed at ANDUA&T, Ayodhya, Uttar Pradesh. These are NM 2, NM 4, NM 7, and NM 8. A variety TharMadhuwas released by CIAH, Bikaner.

Chironji (*Buchanania lanzan*)

Chironji belonging to the Anacardiaceae family, is native to the Indian subcontinent. It is highly adaptable to various soil and climate conditions and is naturally found in the arid and semi-arid forests of Jharkhand, Chhattisgarh, Madhya Pradesh, Rajasthan, Gujarat, and Uttar Pradesh. This medium-sized, sub-deciduous to evergreen plant features a straight trunk and coriaceous leaves. Chironji is a highly heterozygous and cross-pollinated species with a strong tendency for alternate bearing. Its fruits are edible both raw and roasted, with kernels rich in fats (59.0%), proteins (19.0–21.6%), carbohydrates (12.1%), fiber (3.8%), phosphorus (528.0 mg), calcium (279.0 mg), iron (8.5 mg), and vitamins (Khare, 2007). The plant has therapeutic potential to treat conditions such as snakebites, dysentery, diarrhoea, asthma, body inflammation, fever, ulcers, colds, and Alzheimer's. Additionally, it exhibits anti-diabetic and anti-hyper lipidemic properties (Patil and Rothe, 2017).

Varieties

Variety 'Thar Priya' has been identified by ICAR-CIAH, Bikaner. It has a semi-spreading growth habit, thick trunk, dense foliage and dropping branches, umbrella shape, and fruit ripening takes 50-65 days from fruit set. It is a comparatively dwarf, precocious bearer (4^{th} year) and suitable for high density planting. It contains TSS 23.90°Brix, 1.24% acidity, 13.06% total sugars, 6.67% reducing sugar, 48.70mg/100g vitamin C and 31.36% kernel protein. The fruit yield is 11.90 kg/tree.

Mulberry *(Morus alba* L.*)*

Mulberry, a member of the Moraceae family, is native to Southwest Asia. The genus *Morus* includes 24 species, of which 16 are deciduous, with *Morus alba, M. nigra*, and *M. rubra* being predominantly cultivated in commercial orchards. The commercial cultivation of mulberry is primarily focused on silk production and shelterbelts. The emphasis is not given on fruit characteristics. The mulberry fruits are nutritionally dense, containing vitamins, minerals, dietary fibre, sugars, amino acids, carotenoids, flavonoids, and phytosterols. These fruits are utilized as functional foods and pharmacological benefits.

Varieties

A huge diversity exists in the available germplasm pool of mulberry in India. Mulberry, being a perennial and outbreeding tree, exhibitsa high degree of heterozygosis.

There are very few elite lines, and variety was developed in mulberry for commercial fruit production. The promising selections of mulberry, intended for commercial fruit productionhave been identified at ICAR-CIAH, Bikaner, Rajasthan *viz*., Thar Lohit (red fruited) and Thar Harit (white fruited). Thar Lohit was found to be the earliest forthe maturity period. It took 30-35 days to mature. It was found that mulberry genotype Thar Lohit was better than Thar Harit in terms of antioxidant attributes like polyphenol, flavanol, flavonoid and total antioxidant activity.

Annona (*Annona* spp.)

Edible fruits of the genus *Annona* are collectively known as *annonaceous* fruits. Genus *Annona* has 120 species, 6 of them having pomological significance and each one is unique in its taste, flavour, pulp colour and texture. Among these, custard-apple is the most popular one in India which has gained commercial significance in Maharashtra, Gujarat, Madhya Pradesh, Chhattisgarh, Telangana, Karnataka, Andhra Pradesh, Rajasthan, and Tamil Nadu. Others are cultivated on a limited scale, usually in gardens and homesteads. Other lesser-known edible Annona species include *A. reticulata* (Bullock's Heart), *A. diversifolia* (Ilama), and *A. muricata* (soursop). Custard-apple, atemoya, bullock's heart, and cherimoya are normally used as fresh fruits. In recent years, the Annona genus has gained attention as a promising drug candidate due to its remarkable anticancer, antitumor, and cytotoxic properties. The primary phytoconstituents identified in this genus include acetogenins and alkaloids.

Genetic resources

The fruits of Annona species vary in traits, such as size, taste, and texture, and are highly amenable to genetic manipulation, as they crossbreed easily. A total of 62 accessions of Annona species are conserved across different gene banks in India. The maximum number of accessions (29) are maintained at ICAR-IIHR, Bengaluru, followed by MPKV, Rahuri with 21 accessions. ICAR-CIAH, Bikaner conserves 9 accessions, while IIHR-CHES, Bhubaneswar maintains 3 accessions.

Collection

At ICAR-IIHR, sixteen varieties of custard apple (Balanagar, Raidurg, APK-1, Red Sitaphal, Mammoth, Barbados, Washington 07005, Washington 98797, Taiwan, NMK-1, Arka Neelachal Vikram, Phule Janki , Hyderabad Selection, Phule Purandar, Purandar Gold and Arka Sahan) three varieties of Atemoya (Island Gem, Pink's Mammoth and Bullock's Heart) and eight species of Annona - *Annona squamosa*, *Annona atemoya*, *Annona reticulata*, *Annona cherimola*, *Annona glabra, Annona muricata*, *Annona mucosa* and *Annona montana* are conserved in the field gene bank. Other centres conserving Annona germplasm are IIHR-CHES, Bhubaneswar, ICAR-CIAH, Bikaner, and MPKV, Rahuri.

Characterization and evaluation

Existence of variability in landraces indicates ample scope for improvement of annonas found adapted under sub-mountainous tracts of the Aravalli hills. (Bhatnagar *et al.*, 2012). A wide range of variability in physico-chemical attributes of custard apple genotypes showed the scope for superior plant selection based on these parameters (Yadav *et al.*, 2017). Islam *et al.* (1991) studied 27 custard apple genotypes for qualitative and quantitative characters and found considerable variation in landraces for parameters like fruit weight, size, edible portion, taste and TSS. Large genetic diversity is observed among Annonaceae species, although low genetic diversity within *A. muricata* populations had been recorded. Morphological variation of *A. muricata* were observed on a total of 315 samples collected from seven districts of three climatic zones and 133 samples collected from germplasm collections at three national research centres of Srilanka (Padmini *et al.*, 2013). Brisibe *et al.* (2017) characterized key phenotypic attributes and genetic diversity data from 42 representative accessions of the crop as a precursor to enhance a systematic varietal improvement and selection programme that would support conservation.

In the case of *Annona* species, the development of reliable chloroplast markers (rbcL and matK) is appropriate for the discrimination of the most important species of the genus (Larranaga and Hormaza, 2015). These specific markers based on matK and rbcL sequences were developed for 7 closely related *Annona* species of agronomic interest (*Annona cherimola, A. reticulata, A. squamosa, A. muricata, A. macroprophyllata, A. glabra*, and *A. purpurea*). The primers generated were validated in six additional species of the genus (*A. liebmanniana, A. longiflora, A. montana, A. senegalensis, A. emarginata* and *A. neosalicifolia*) and in an interspecific hybrid (*A. cherimola* x *A. squamosa*) as reported by Nerea Larranaga and José I. Hormaza, 2015.

Conservation

For conservation, *in-situ* efforts are sporadic and mostly limited to backyard gardens, focusing on species like soursop, custard apple, and sugar apple. The conservation and use of genetic resources of Annonaceae edible fruits were studied through a survey conducted in 2010 by the National Network of Annonaceae of the National Plant Genetic Resources. Conservation, characterization, and *ex-situ* collection of the genetic resources of custard apple are essential. *Ex-situ* conservation is practiced through gene

banks or collections, but only for soursop, cherimoya, and llama, where limited accessions available. However, due to the non-orthodox nature of the seeds, long-term conservation remains a challenge. These conserved plant genetic resources can serve as sources for breeding approaches aimed at improving yield, quality, nutritional value, and resistance to abiotic stresses, thus ensuring livelihood and health security (Sushmitha and Sakthivel, 2023).

Varietal development

Custard apple varieties are broadly grouped based on external fruit color into green, red, and yellow custard apples. Most of the commercial cultivars released in India and abroad were developed from open-pollinated progenies and chance seedlings. These are 'Mammoth', 'Green Sitaphal', 'Red Sitaphal', 'Balanagar', 'Barbados, 'Islander', Red Israel', Washington P1107-005, Washington P198797, British Guinea and Brandy (Rymbai *et al.*, 2014). The hybridization efforts are ongoing in custard apple at ICAR-IIHR, Bengaluru and MPKV, Rahuri, where several promising hybrids, including Hybrid No. 6, Hybrid No. 13, and Hybrid No. 22 have been identified. Some of the famer's varieties such NMK, Saraswati is also popular among the growers.

Ber (*Ziziphus mauritiana* Lamk.)

The Indian jujube, Ber, belongs to the family Rhamnaceae. This fast-growing tree features a spreading canopy, a short bole, and slender, downy branches with paired brown spines and known for its drought-hardiness, the ber tree thrives in arid and semi-arid regions due to its deep taproot system and xerophytic adaptations, such as leaf shedding during peak summer to reduce transpiration, waxy and hairy leaves, and thick bark.

Genetic resources

The diversity in ber is widespread across various growing regions of India, particularly in dry and arid areas. This diversity presents significant opportunities for improving key traits of the fruit, such as yield, quality, and resistance to environmental stresses. Maximum variability in ber is available in dry parts of country as well as desert.

Collection

A wide range of ber germplasm, including species, cultivars, and other varieties, has been collected from different research stations across the country and is being conserved in field gene banks at ICAR-CIAH, Bikaner, ICAR-NBPGR, RS Jodhpur, MPKV, Rahuri, CCS HAU, Hisar, ICAR-CAZRI, Jodhpur, PAU RS, Bahadurgarh, and SDAU, S.K. Nagar. Among these, ICAR-CIAH, Bikaner is maintaining the largest collection, with 318 accessions.

Varieties

Over 150 cultivars of ber are cultivated across India, many of which have been developed through selection methods in different regions. These varieties exhibit a wide range of characteristics, making them suitable for diverse agro-climatic conditions. The promising cultivar under commercial cultivations are Gola, Seb, Banarsi Karaka, Banarsi Pebandi, Kaithali, ZG-1, Sanaur-1, 2, 3, 4, Katha, Umran, Mundia, Chonchal, Illaichi, Rashmi, etc. (Shukla *et al.*, 2011). B.S.75-1 variety of *ber* has been developed from CCS HAU, RRS, Bawal which is resistant against fruit fly and powdery mildew.

Hybridization work is in progress at HAU, RRS, Bawal and highest fruit yield was obtained in Hybrid-1 (64.7 kg/tree) and incidence of powdery mildew was negligible followed by Hybrid-10 (63.7 kg per tree) (Anonymous, 2011). Narendra Ber Selection-1 has been released from ANDUA&T, Ayodhya and it is performing well under climatic conditions in Eastern UP (Anon, 2011). The new promising ber varieties such as Thar Sevika, Thar Bhubharajand Thar Malti were developed by CIAH, Bikaner for cultivation in arid conditions has been released (Shukla *et al.*, 2004).

Khirni (*Manilkara hexandra* L.)

Khirni also known as Rayan, is part of the Sapotaceae family and native to India. This evergreen, medium-sized, slow-growing fruit tree has a spreading canopy and thrives in arid, semi-arid, and tropical climates, often serving as an avenue tree or bonsai due to its dense foliage and compact growth habit. Khirni flowers in February–March, with fruits ripening by May–June. It is also used as rootstock for sapota owing to its drought and salinity tolerance. The tree's bark, seeds, and fruits are rich sources of tannins, oils, and vitamin A, respectively.

In India, this species is occasionally cultivated in backyards, homestead gardens, public parts as avenue tree and in farmers' fields near villages due to its economic importance as fruit tree having nutritional and medicinal properties. The production in India is mainly concentrated in the drier states and the produce is collected by the villagers and sold in the local market. Its cultivation may be spread to arid and semi-arid areas, resource poor areas and wastelands where other crops cannot be grown successfully.

Varieties

States of Rajasthan, Gujarat, Madhya Pradesh, Bihar, Jharkhand, Orissa, Andhra Pradesh and Maharashtra have rich diversity of khirni. Recently, an improved variety 'Thar Rituraj' has been developed by ICAR-CIAH, Bikaner, whichis semi-dwarf, precocious bearer (4th year),

fruit ripens in 120-125 days from fruit set. It is suitable for table and processing purpose. The fruit yield is 10-16 kg/ plant.

Cactus pear (*Opuntia ficusindia* (L) Mill.)

Cactus pear is known as 'Prickly pear' or Cactus fig or Tuna. It belongs to the family Cactaceae. Genus *Opuntia* has nearly 300 species, out of them 12 species are grown for fruits, vegetables and fodder purposes. Being a succulent xerophytic plant, it is ideally suited to water-scarce dry zones of the world. It requires low energy inputs to provide food and fodder for humans and livestock. It is a most suitable plant for semi-arid and arid regions. In India, it is found in a wild state and under-utilized fruit. However, it is a National Crop of Mexico. The cactus pear is commercially cultivated in countries like the USA, Israel, Chile, Peru, Brazil, Bolivia, Argentina, Italy, Tunisia, the Middle East, and South Africa. It is a xerophytic spiny or spineless plant. It has a shallow, fibrous root system. Roots are developed when the areoles are in contact with soil. The plants have thick succulent stems called 'cladodes'. These cladodes or cactus stems have numerous areoles, which function like meristematic buds. The buds develop into new cladodes and fruits (aerial parts) and roots (underground parts) with the passage of time.

Genetic resources

There is no indigenously identified variety of cactus pear. However, as a part of an Indo-US collaborative research program on *Opuntia* in India, 33 *Opuntia* clones were introduced at Nimbkar Agricultural Research Institute at Phalton, India, in 1987. All these clones grew well under the semi-arid agroclimatic of western Maharashtra, and it is reported that some clones also produced fruits (Meghwal and Singh, 2016). In 1991, the Central Soil Salinity Research Institute, Karnal obtained five fruit, forage, and vegetable clones from Dr. Peter Felker's collection in Texas, USA. Again, in January 1997, 51 additional *Opuntia* clones were introduced from Texas A&M University-Kingsville at the ICAR-CIAH, Bikaner. Among them genotype 1269 performed better in terms of survival and cladode exceptions. Another germplasm exchange contained thorny and thornless varieties of red, orange, yellow, and lime-green fruits that ranged up to 200 g in fruit size. Forty-three exotic collections were introduced at ICAR-CAZRI, Jodhpur during 2010.

Evaluation

The evaluation of introduced germplasm at Jodhpur in Rajasthan and Bhuj in Gujarat has indicated the latter to be the better location for its growth. High summer temperature and dry atmosphere (low humidity) is not conducive for its optimum growth and therefore, its performance has not been very encouraging at Jodhpur.

Fig (*Ficus carica* L.)

Fig is one of the earliest cultivated deciduous fruit trees. It belongs to the family Moraceae. Although its precise origin remains uncertain, fig is believed to have originated in Western Asia and spread to northern India, with local varieties extensively cultivated in Mediterranean countries. The genus *Ficus* includes more than 700 species, mainly spread in the tropics. This fruit species seems to be evolved from *F. carica* var. *rupestris*, which spread throughout the Mediterranean Basin before being domesticated, with various simultaneous selection focuses in this area. The use of this plant by humans is ancestral, and there are archaeobotanical evidences that indicate the use of parthenocarpic fruits and the possible culture of fig 14,000 years ago, showing that fig was the first domesticated crop of the Neolithic Revolution. In India, fig cultivation is confined mostly to western parts of Maharashtra and Gujarat, Uttar Pradesh, Karnataka, and Tamil Nadu.

Varieties

Poona Fig is the most popular cultivar in our country. A mature Poona Fig tree yields 25–30 kg of fruit per plant after five years of growth, with an average fruit weight of 30–60 g and TSS content of 18–20°Brix.

Dinkar: It is an improvement over cv. Daulatabad for yield and quality. It is a recently identified variety, which resemble Poona Fig variety in fruit characteristics.

Deanna: Produces medium to large golden-yellow fruits with strawberry pulp, suitable for dried fig production. The fruits are large (up to 46.64 g), with high TSS (21.20°Brix) and low acidity (0.15%), ensuring superior colour, flavour, and texture in processed products.

Excel: It develops smaller canopies, making them ideal for high-density planting.

Conadria (synonyms: Adriatic Hybrid, Verdone Hybrid): A hardy hybrid that produces medium to large, pyriform, yellow-green fruits with light strawberry pulp and a rich flavor.

Evaluation

Three varieties of fig viz., Black Ischia, Puna and Dinkar were evaluated at ICAR-CAZRI, Jodhpur. The variety Dinkar was found best with fruit yield of 10-15 kg per plant with larger fruit size and high TSS (12-14°Brix). The variety Black Ischia was at par with respect to yield but fruit size and TSS content (10-12°Brix) was less. The exotic varieties Deanna, Excel and Conardia performed well at Bengaluru.

Jharber (*Ziziphus nummularia* Burm. f.)

Jharber is a perennial, deciduous, thorny shrub, 1–2 m in height, with drooping branches. It is naturally found in a variety of habitats in extremely arid environments, including crop fields, grazing lands, sandy-saline areas, rocky terrain, and degraded pastures (Rathore, 2009). Its anatomical adaptations, such as papillae, crypt stomata, a thick outer epidermal wall, a robust cuticle, and a deep taproot system, enable exceptional tolerance to drought, salinity, and high temperatures, making it well-suited for survival in extremely arid regions (Padaria*et al.*, 2016; Uchoi *et al.*, 2022). The shrub flowers from July to August, and its fruit ripens between November and December.

The fruit is a small, globose-ovoid drupe, dark red, with a limited amount of sub-acidic edible pulp. Dried fruits of jharber contain triterpenoids, alkaloids, and saponins, which contribute to their medicinal properties, including anticancer, stomachic, sedative, blood-purifying, anti-obesity, antipyretic, anodyne, refrigerant, pectoral, anti-anemia, anti-vomiting, and styptic effects. The leaves, locally called 'Pala,' are a valuable source of fodder for camels, cattle, goats, and sheep, as they are rich in crude fiber, crude protein, calcium, and phosphorus (Bohra and Ghosh, 1981). Furthermore, different parts of the plant have traditional medicinal uses: Leaves are applied as poultices for wound healing and are used to treat asthma, fever, gum bleeding, and liver issues. The bark is used to manage diarrhea. Roots are consumed as a decoction for fever treatment or powdered to heal ulcers and wounds. Fruit acts as a laxative and antiemetic. Seeds possess sedative properties (Singh and Meghwal, 2020). This multipurpose shrub plays a vital role in both ecological and medicinal contexts, particularly in arid regions.

Pilu (*Salvadora persica* L.)

Pilu is an indigenous drought hardy species found growing naturally mostly in Rajasthan and Gujarat and also to some extent in Punjab. Another species under the genus is *S. persica* which is also equally important. It is highly resistant against abiotic stresses such as drought and salinity. In Gujarat, it occurs near the coastal areas and along the tidal creeks in Maharashtra where it is a boon to wasteland development. It is abundantly found in Jalore, Barmer, and Jodhpur district in western Rajasthan. Shankar and Kumar (1987) have also reported its abundance in the peripherals of all major runs of Jaisalmer district. The maximum density (120 trees/ ha) of *S. oleoides*was recorded at Shantipura area followed by Bibasar area (112 trees/ ha) in Jalore district of Rajasthan. Its density varies from 5 to 78 trees/ ha depending upon the soil types and rainfall. The rainfall range of the species is between 180 to 700 mm per annum and it can tolerate maximum temperature up 50°C and a minimum of 4°C.

On the farm boundaries, the rows of the plants act as wind breaks preventing soil erosion. Its ability to grow under harsh climatic condition of desert areas provides a pleasant site during summer months under which large number of wild animals and birds get shelter and protection. It is small to medium sized evergreen tree with dense foliage. It coppices fairly well and regenerates freely by root suckers. Apart from edible fruits, other parts of the tree also have economic value. Leaves are very good feed for animals especially goats and camels while the twigs are used for cleaning the teeth. The other plant parts such as root bark and leaves etc. have value in folk medicine. It grows upto 5 m height, gregarious, evergreen with dense round crown and has deep as well as lateral root system to utilize the moisture according to availability. The species flowers during January to April and ripe fruits called "*peelu*" are available during May-June. The ripe fruits are sweet but immature fruits are highly acrid. The fruit contains small seeds which is about 10% of fruit weight. The fruit yield ranges between 30-80 kg per plant.

Manila Tamarind (*Pithecellobium dulce* (Roxb.) Benth.)

Manila Tamarind also known as Madras thorn, Monkey pod, or *Jungle jalebi*, belongs to the Fabaceae family. This versatile, fast-growing, medium-sized thorny tree is used as live fencing, animal fodder, hardwood timber, windbreaks, and as a potential source for lac culture. Its fruits have a sweet-acidic taste and are rich in dietary fiber, proteins, calcium, iron, phosphorus, unsaturated fatty acids, and antioxidants (Brewbaker, 1992). The fruit is utilized for treating toothaches, mouth ulcers, sore gums, dysentery, chronic diarrhea, stress, aging symptoms, and skin pigmentation.

PKM (MT)-1: This variety was developed as an open-pollinated seedling selection from Soolakkarai in Virudhunagar district, Tamil Nadu. It is a hardy plant that thrives in sandy, saline, and alkaline soils, and is particularly suited for rainfed areas. The fruits are spirally twisted with pale yellow pods and white arils, yielding about 79 kg per tree annually, with a potential maximum yield of 125 kg per tree (https://agritech.tnau.ac.in/horticulture/horti-TNAUvarietiesfcmtamarind.html)

Tendu/ Timroo (*Diospyros melanoxylon* Roxb.)

Tendu/Timroo belongs to the Ebenaceae family and is native to India and Sri Lanka. It thrives in limited endemic regions, including Gujarat, Madhya Pradesh, Rajasthan, Jharkhand, Bihar, Chhattisgarh, and Tamil Nadu. This long-lived, deciduous, dioecious, seedless parthenocarpic berry-producing tree is recognized for its leaves, which are extensively used for making bidis (traditional cigarettes), as well as in agricultural tools and furniture. It is also a bio-indicator for high sulfur dioxide concentrations (Behera and Nath, 2012).

Tendu fruits boast high phenolic content, flavonoids, antioxidants, scavenging properties, and β-carotene levels comparable to or exceeding those of guava, plum, star fruit, mango, kiwi, and apple. Its bark extract is traditionally used to treat dyspepsia, diarrhoea, and smallpox (Hmar *et al.*, 2017).Currently, there are no officially developed or named varieties of Tendu. However, efforts are focused on selecting superior genotypes from natural populations for propagation and cultivation. Tendu plays a vital role in rural livelihoods and forest economies.

Way ahead

Several underutilized and wild fruits naturally grow in arid and semi-arid regions. These fruits have been used by the local inhabitants since time immemorial. Very little attention has been given on the collection, conservation and evaluation of these fruits. Climate change, changing land-use patterns, deforestation and expansion of major fruits are the threats to the diversity of these crops. There is a need for comprehensive efforts for exploration, collection, conservation and utilization of these fruits. The research efforts have been made on some fruits, and several promising lines have been identified. The collection and conservation of germplasm of these fruits should be a priority as genetic erosion is occurring at a rapid pace due to loss of habitat. Besides, it will be necessary to identify areas with elite populations in the wild and/or in protected/managed areas, so that *in-situ* conservation of these species could be promoted. There is a need to select genotypes that are shorter in stature, regular in bearing, fewer seeds/ smaller stone, and better fruit quality. The morphology and qualitative variability present in these species can be exploited through hybridization.

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Conflict of Interest

The authors declare no conflict of interest.

Data Sharing

This review article did not generate any supplementary data.

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