

Underutilized fruits of arid & semi-arid regions for nutritional and livelihood security

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ABSTRACT

*Underutilized fruits are considered as mines of nutrients and antioxidants. Despite being highly nutritive with medicinal attributes and their ability to grow under adverse soil and climatic conditions, they have not received the desired attention. However, these underutilized fruits are integral part of traditional foods, especially in rural areas and among tribal communities. A wealth of flora such as Lasoda (*Cordia myxa*), Ker (*Capparis decidua*), Phalsa (*Grewia subinaequalis*), Pilu (*Salvadora oleoides* and *S. persica*), Karonda (*Carissa carandus*), Wood apple (*Feronia limonia*), Bael (*Aegle marmelos*), Jamun (*Syzygium cumini*), Khirni (*Manilkara hexandra*), Chironji (*Buchnanania lanzan*), Cactus pear (*Opuntia ficus indica*), Mulberry (*Morus* spp.) etc. harbors the arid & semi-arid ecosystem which are to be optimally utilized. The recent awareness regarding the potential of these ecologically fragile lands for production of quality horticultural produce has not only opened up scope for providing economic subsistence for the people of these regions, but also for bringing new areas to increase fruits production. Besides, the underutilized fruits have a wide scope of export for various processed products. In the present article, attempt has been made to present a succinct description of scope, nutritive values, uses, and improved varieties of underutilized fruits of arid & semi-arid regions.*

Keywords: Minor fruits, biodiversity, nutritional security, value addition

Arid refers to prolonged dryness, and is used with regards to the climate itself, and the land below it. In such regions the ability to produce agricultural crops is limited. In general, on arid lands the potential evaporation of water from the land exceeds the rainfall. In India, a vast land resource 39.54 mha (~12% of the total geographical area) and 169 mha (~53% of the total geographical area) falls under arid and semi-arid regions, respectively. The arid agro-eco region encompasses south-western parts of the states of Punjab and Haryana, western parts of Rajasthan, Kutch peninsula and northern part of Kathiawar peninsula in Gujarat State. The semi-arid regions include Karnataka, interior Tamil Nadu, western Andhra Pradesh and central Maharashtra. These regions are characterized by extremes of both high and low temperatures, low & erratic rainfall, low relative humidity, high potential evapo-transpiration, high sunshine, abundant solar energy and high wind speed, particularly, during summers. These regions consist of vast sandy and other wastelands, which have productivity constraints such as salinity in soil and irrigation water, low soil fertility and extreme climatological stress conditions.

India holds a prominent position in horticulture and has emerged as the second largest producer of fruits and vegetables in world (Anon., 2017). India is home to many fruit crops. Fruits like mango, banana, citrus, apple, guava, papaya, pomegranate, grapes, sapota, pineapple, litchi etc. are well known in both local and international markets, and their country-wise production and export data are also available. . These fruit crops are being grown in different parts of the country as commercial fruit crops in organized orchards and prospered continuously due to their economic, nutritive, social and religious values. Many of them were supported and improved by villagers, growers and horticulturists for wide adoption due to their acceptable flavour and delicious taste (Bhardwaj and Pandey, 2011). On the other hand, underutilized or minor fruits are not so extensively cultivated and their consumption and trade tend to be more limited, geographically and quantitatively, than those of the major fruits (Saúco, 2013) despite being highly nutritive with medicinal attributes and also their ability to grow under adverse soil and climatic conditions. But these so-called underutilized/ minor fruits remained uncared and

confined mainly natural wild, semi-wild and semi-domesticated conditions, albeit with large ever increasing genetic diversity. The underutilized fruits are integral part of traditional foods, especially in rural areas and among tribal communities. A wealth of flora harbors the arid & semi-arid ecosystem which has remained to be optimally utilized. These includes *Lasoda* (*Cordia myxa*), *Ker* (*Capparis decidua*), *Phalsa* (*Grewia subinaequalis*), *Pilu* (*Salvadora oleoides* and *S.*

persica), *Karonda* (*Carissa carandus*), Wood apple (*Feronia limonia*), Bael (*Aegle marmelos*), Jamun (*Syzygium cumini*), Khirni (*Manilkara hexandra*), Chironji (*Buchnanania lanzan*), Cactus pear (*Opuntia ficus indica*), Mulberry (*Morus* spp.), Marula nut (*Sclerocarya birrea* subsp. *caffra*) etc. (Singh *et al.*, 2018). Due to hardy plant types, these fruits can thrive well under drought situations, which is common in arid & semi-arid regions. The recent awareness regarding the potential of these

Table 1: Some important underutilized fruit crops of arid & semi-arid regions.

Some underutilized fruit crops presently grown under Indian arid & semi-arid regions			
S. No.	Botanical name	Family	Common name
1.	<i>Ziziphus rotundifolia</i>	Rhamnaceae	<i>Boradi</i>
2.	<i>Ziziphus nummularia</i>	Rhamnaceae	<i>Jharber</i>
3.	<i>Cordia</i> spp.	Boraginaceae	<i>Goonda, Lasoda, Indian cherry</i>
4.	<i>Caparis decidua</i>	Capparaceae	<i>Ker, Kirir, Karril</i>
5.	<i>Grewia</i> spp.	Tiliaceae	<i>Phalsa</i>
6.	<i>Salvadora</i> spp.	Salvadoraceae	<i>Pilu, Jaal, toothbrush tree, mustard tree, mustard bush</i>
7.	<i>Acacia senegal</i>	Fabaceae	<i>Kumat</i>
8.	<i>Syzygium cumini</i>	Myrtaceae	<i>Jamun, jambolan, Java plum or black plum</i>
9.	<i>Carissa carandas</i> L.	Apocynaceae	<i>Karonda, Christ's thorn</i>
10.	<i>Buchanania lanzan</i>	Anacardiaceae	<i>Chironji, charoli, Almondette tree</i>
11.	<i>Madhuca indica</i>	Sapotaceae	<i>Mahua, Indian Butter Tree</i>
12.	<i>Manilkara hexandra</i>	Sapotaceae	<i>Khirni, Rayan, Ceylon Iron Wood, milk tree, wedge-leaved ape flower</i>
13.	<i>Pithecellobium dulce</i>	Leguminosae	<i>Jungle Jalebi, Madras thorn, Manila tamarind</i>
14.	<i>Grewia subinaequalis</i>	Tiliaceae	<i>Gangana, White Crossberry, Phalsa Cherry, Raisin Bush</i>
15.	<i>Morus</i> spp.	Moraceae	<i>Mulberry, Sehtoot</i>
16.	<i>Ficus</i> sp.	Moraceae	<i>Fig, Anjeer</i>
17.	<i>Feronia limonia</i>	Rutaceae	<i>Wood apple, Elephant apple, Organic limonia, Kaitha</i>
Some potential exotic underutilized fruit crops Indian arid & semi-arid regions			
S. No.	Botanical name	Family	Common name
1.	<i>Opuntia ficus indica</i>	Cactaceae	Cactus pear, Indian fig opuntia, Barbary fig, Spineless cactus and Prickly pear
2.	<i>Ceratonia siliqua</i>	Fabaceae	Carob tree or Carob bush. Locust bean
3.	<i>Spondias tuberosa</i>	Anacardiaceae	Imbu
4.	<i>Argania spinosa</i>	Sapotaceae	Argan tree
5.	<i>Adansonia digitata</i>	Malvaceae	Baobab, Monkey bread tree, Lemonade tree, Upside down tree
6.	<i>Cordeanxia edulis</i>	Fabaceae	Yeb-eb nut, Ehb, Qud
7.	<i>Sclerocarya birrea</i>	Anacardiaceae	Marula nut, Mufula, Shea nut
8.	<i>Santalum acuminatum</i>	Santalaceae	Quandong, Native peach
9.	<i>Uapaca kirkiana</i>	Euphorbiaceae	Musuky, Sugar plum or mahobohobo
10.	<i>Dovyalis caffra</i>	Salicaceae	Kei apple, Umkokola
11.	<i>Bosciasenegalensis</i>	Capparaceae	Kursan, Hemmet, Bokkhelli
12.	<i>Schinziophyton rautanenii</i>	Euphorbiaceae	Mongongo tree, Mongongo nut or Manketti tree
13.	<i>Lannea acida</i>	Anacardiaceae	Bembe

ecologically fragile lands for production of quality horticultural produce has not only opened up scope for providing economic subsistence for the people of these regions, but also for bringing new areas to increase fruits production. The underutilized fruits have a wide scope of export for various processed products.

Bioversity International recommended that underutilized fruits can be used as alternative sources to combat hidden hunger (Khoo *et al.*, 2008). The underutilized fruits are integral part of traditional foods, especially in rural areas and among tribal communities. In ancient times, these underutilized fruits were the main source of food and medicines to rural and tribal people. However in present time, their use in daily life has been reduced, primarily, owing to lack of awareness about their potential. Therefore, it is important to include these fruits in health promotion campaigns. This is the need of the hour to focus on this important and economically rewarding area of horticulture (Nandlal and Bhardwaj, 2014).

SCOPE OF UNDERUTILIZED FRUITS IN ARID & SEMI-ARID REGIONS

1. In arid & semi-arid regions, a large part of land is considered as marginal/problematic/waste lands, which are unfit for cultivation of high input demanding nature crops. Such lands can easily be put to use for growing low input requiring crops like underutilized fruits in order to diversify the present day horticulture, which is so inevitable in view of the increasing population pressure, nutritional security and fast depletion of natural resources as well as the growing and changing consumer's needs.

2. In most of the arid and in a substantial parts of semi-arid region the horticultural crops productivity is less than the desired productivity level. As cultivation of field crops is unremunerative in such ecosystem due to prevailing environmental constraints and limited irrigation facilities, diversification with the underutilized fruit crops in the conventional cropping system can bridge the gap between increasing demands and supply of food. It is possible to realize the untapped potential of these regions through resorting to cultivation of location specific minor fruit crops. Production of underutilized fruits can further be

improved through adoption of modern cultivation practices.

3. Beside nutritional & social security, hitherto untapped export potential, underutilized fruit crops has a vast potential for production of value added products, with high therapeutic, medicinal values and antioxidant properties on one hand and free from the residue of toxic chemicals on the other as such crops are grown with minimum agricultural inputs.

1. Importance of underutilized fruit crops

1. Provide variety of products that include food, fodder, fuel wood, gums, resins, fibre, medicine etc.
2. Easier to grow and hardy in nature, producing a crop even under adverse soil and climatic conditions.
3. Most of them are very rich sources of vitamins, minerals, and other nutrients such as carbohydrates, proteins, fats and nutraceuticals.
4. Cheap and readily available.
5. Vital source of genes against biotic and abiotic stresses.
6. Low input requiring crops.
7. Produce higher biomass than field crops per unit area resulting in efficient utilization of natural resources.
8. Can help achieving ecological security through improvement of wastelands by preventing soil erosion, improving fertility of soil and promoting biodiversity.

REINFORCEMENT OF NUTRITIONAL SECURITY

There are several underutilized fruits (*jamun*, *chriounji*, *mahua*, *lasoda*) which are very rich in vitamins, minerals, fat, carbohydrates and antioxidant which have not been exploited well. There are some fruits which are rich source of protein also (*chirounji*, wood apple, *ker*) which are otherwise obtained from pulses and vegetables. Strong campaigning is essential to create awareness among producers and consumers about the importance of underutilized fruits, so as to produce in larger quantity for continuous supply of raw materials to the industries. The nutritive value of

Table 2: Nutritive value of some underutilized fruits per 100 g edible portion.

Fruit	Calorie (Kcal)	Protein (g)	Fat (g)	CHO (g)	Fibre (g)	Ca (mg)	P (mg)	Fe (mg)	Vit. A (IU)	B ₁ (mg)	B ₂ (mg)	Niacin (mg)	Vit. C (mg)
Chirounji	-	19.0	59.1	12.1	3.8	279	528	8.5	-	0.69	6.53	1.5	5
Jamun	83	0.53-0.65	0.1	18.7	0.9-1.2	20	10	100	90	-	-	-	35.0
Karounda	42	1.1	2.9	2.9	1.5	21	38	39.1	-	-	-	-	10.0
Khirni	-	0.48	2.42	27.74	-	83	17	0.92	-	-	-	-	15.62
Mahua-flower	-	-	-	21-25	-	-	-	-	586-890	-	-	-	51-72
Wood apple	-	7.3	0.6	-	-	4	9	0.5	0.17	0.04	-	0.8	3
Jangal jalebi	78.8	2.0-3.3	0.4-0.5	18.2-19.6	1.1-1.2	13	42	0.5	25	-	-	-	138
Ker	100	5.9	1.23	20.87	-	153.8	-	50.8	2.0	-	-	-	133
Phalsa	72.4	1.3-1.58	0.90-1.82	14.78	1.2-1.77	129	39	3.1	800	-	-	-	22
Lasoda	65	1.8-2.0	1.0	12.2	0.3	40	60	-	-	-	-	-	-
Pitu fruits	-	6.0	2.0	76	2.0	630	167	8.0	-	-	-	-	2.0
Pitu seeds	-	-	45.5	23.5	5.8	-	-	-	-	-	-	-	-
Mulberry	-	0.4-1.5	0.4-0.5	8-9	0.9-1.4	-	-	-	-	-	-	-	12

some underutilized fruits is given in table 2 (Saroj and Prakash, 2012; Singh *et al.*, 2018).

The status of germplasm of some underutilized fruits, genetic diversity, nutraceutical values, uses, production and management practices for achieving higher yield and quality of fruits in arid regions are being discussed in the subsequent paragraphs;

1. Lasoda (*Cordia myxa* Roxb.)

It is known as Indian cherry, *lehsua* or *goonda*. The other important species are *C. gharaf* (*goondi*), *C. rothii*, *C. macleodii*, *C. vestita* and *C. wallichii*. Out of these, *goondi* (*Cordia gharaf*) is a popularly grown species. Medium size tree having dense foliage with crooked trunk. *Lasora* leaves have sunken stomata and other characters of drought tolerance. Plants are deciduous in nature (Singh *et al.*, 1996). The vegetative growth is very fast in *lasora* plant. New flush comes in spring (March) when plant enters in flowering phase. Bunches are of light yellow colored with hermaphrodite fragrant flowers borne auxiliary on current season growth. Flowering in *lasoda* is reported to change from place to place during the period of March-April in arid region (Pundir, 1987). The duration of flowering varied from 41 to 50 days and the peak flowering reached 16 days after the first flower initiation. The development of flower bud takes about 21-22 days. The fruit is 2.0-3.0 cm long, round in shape and yellowish brown colour at maturity. Immature green fruits are available in April-May while ripe fruits are available during June-July. Fruits are mucilaginous with a stone (Singh and Vishwanath, 1991).

Varieties : A large variability exists in plantation of *lasoda* in relation to morphological characters, particularly, plant height, spread, leaf size, fruit size; fruiting behaviour; quality parameters such as fruit colour (yellow, pink, dark pink), pulp content, sweetness, pickling quality, seed and pulp ratio etc. as a result of seed propagation. There are two identified varieties of *lasoda* viz., Thar Bold and Maru Samridhi.

Thar Bold : A prolific and early bearing *lasoda* has been identified through selection at ICAR-CIAH, Bikaner. It bears bold fruits in cluster with production of 1.5-2.0 q tender fruits/ tree/ year. The

tender fruits are suitable for making vegetable, pickles and for dehydration purpose. Fruits are also utilized as table fruit and for processing purpose. This variety is recommended for commercial cultivation both as block plantation and a component of agro-forestry system in arid and semi-arid regions.

Maru Samridhi : This variety was identified by ICAR-CAZRI, Jodhpur. Growth habits of plants are drooping in nature. It bears on an average 14 fruits per bunch. Each fruit weighs around 10 g and plant yields 90 kg per tree.

Nutraceutical value : Studies conducted at ICAR-CIAH, Bikaner has shown that the *lasoda* fruits are good source of different antioxidants, which are presented hereunder;

Table 3. Antioxidant attributes of *lasoda*.

S. No.	Attributes	Contents
1	Polyphenols (mg/100g)	137.56
2	Flavanol (mg/100g)	14.32
3	Flavonoid (mg/100g)	434.28
4	<i>o</i> -dihydric phenol (mg/100g)	45.67
5	Total AOX activity (MTE/100g)	10.67

Uses: Green fruits are used for preparing vegetable and delicious mixed pickle. In spite of high nutritive and medicinal value in fruits, leaves and barks are also having medicinal property. Fruit is used as anthelmintic, diuretic demulcent and expectorant. It is used in disease of the chest and urinary passes. The kernels are used in external application for ringworm. A decoction of the bark is used in dyspepsia and fevers. Glue is also prepared from the mucilaginous pulp of *lasora* fruit. Plant gives light timber used for various domestic purposes. However, wood is light in weight and is used for making boat and agricultural implements. Stem barks contain 2% tannin.

2. *Ker* (*Capparis decidua* Forsk.)

It is one of the prominent unexploited plants found in the Indian desert. It is an ancient fruit of Indian subcontinent. In India *ker* is known for its medicinal and religious uses from antiquity. The medicinal and nutritive value of *ker* has been appreciated which is used to prepare various ayurvedic medicine and nutritive dishes (Anon,

1960). In Panchkuta, the important dish of arid region, dehydrated *ker* makes the major component. It is also used for pickle and dehydration. *Ker* is rich source of protein, phosphorus, potash, calcium and magnesium. Besides fresh consumption, it has processed value and therefore, emphasis is required on its large scale cultivation in arid and semi arid regions.

Ker is multipurpose plant species, which every plant part is used by the local people. Fruits are highly nutritious and medicinally important. *Ker* tree is boon for Thar Desert. Stem wood of *ker* is very strong and durable. It is used to make the pivots of stone mill. Thick wood of *ker* is used to make foundation around the well (Chandra et al., 1994) where as smooth thin wood of light yellow colour is used for making small agricultural implements (Singh, 1993). *Ker* wood resists the termite attack and therefore, thinner branches are used for fencing the field and mulching. It is also used as fuel wood in rural areas. The young twigs serve as a fodder for camels and goats. Immature flower buds and flowers of *ker* are used for vegetable and pickling purpose. The use of immature flowers buds and flowers of *Capparis decidua* as vegetable is described in literature. *Ker* flowers have also been tested for cercaricidal properties.

Varieties: Under natural populations, rich genetic diversity with a wide range of variability occurs in *ker* in habit, fruit size, colour of fruits, petals, pulp content, spiny habit, spreading of branches and compactness of canopy, and time of flowering and fruiting. However, no systematic efforts have been made so far to collect and conserve plants representing this diversity or to promote the most desirable variants. There is a need to identify suitable types with the view of selecting plants that are heavy yielding, have large fruit size and high pulp content, are rich in protein; of the proper total soluble solids (TSS), tartness, less acid, with small and soft seeds, etc. In general two distinct plant types of *ker* occur: a tree form, which is relatively unusual, and a shrub form, in the majority of plants.

Table 4: Antioxidant properties of ripe *ker* fruits.

S. No.	Attributes	Ker pulp	Ker seed
1	Polyphenols (mg/100g)	106.48	31.87
2	Flavanol (mg/100g)	13.56	14.55
3	Flavonoid (mg/100g)	196.41	81.09
4	<i>o</i> -dihydric phenol (mg/100g)	29.0	16.79
5	Total AOX activity (MTE/100g)	6.74	1.74

Nutraceutical value: Studies carried out at ICAR-CIAH, Bikaner has suggested that the *ker* has high contents of different antioxidants, which are presented hereunder;

Uses: Immature tender green as well as pink/red ripe fruits of *ker* is used in various ways (Chauhan *et al.*, 1986; Chundawat, 1990; Chandra *et al.*, 1994; Singh, 1993). It has been mentioned that unripe *ker* fruits are pickled and or cooked as vegetable which forms an integral part of the diet of people in desert and semi-desert areas of the country where as the ripe fleshy fruits are eaten by birds. Chundawat (1990) however, described that *ker* fruits are mainly used in pickling or as vegetable when immature while sweet and acrid fruits are enjoyed by children in natives after ripening. Chandra *et al.* (1994) described the use of *ker* fruits at various stages. They mentioned that unripe green fruits after processing are eaten as vegetable and also used for making pickle, whereas, mature unripe fruit contain high level of glucosinolates and can only be used at limited scale after proper processing. Rai (1987) reported that *ker* seed contains 20% saturated hydrocarbons and ketones with C28 to C32 chain lengths and 0.7% sugar along with 8.6% protein.

3. *Phalsa* (*Grewia subinaequalis*)

It is a minor fruit crop of sub-tropical region. It is native to India. It is one of the most hardy fruit plant, drought resistant and thus requires little care with low inputs. It can be grown almost in all parts of north India except at higher elevations. It is mainly grown in the states of U.P., Bihar, Rajasthan, Haryana, Punjab, Gujarat, Maharashtra, Andhra Pradesh and Madhya Pradesh. *Phalsa* being very vigorous in growth can be an ideal plant for plugging gullies and ravines and for contours to protect bunds. The plants are multiplied through seeds and stem cuttings. Being a bush, it can be

grown as filler plant in *aonla*, *bael*, *ber* orchards. It is mainly propagated through seeds and stem cuttings. The small fruits have to be picked from bush several times during the fruiting season and thus the cost of production is increased considerably. It is a small bush and bears many berries like fruits. Fruits ripen by the end of May and beginning of June. Fruits are perishable and keeping quality is very less.

Varieties: In general, no remarkable variability has been found in *phalsa* except erect and bushy type plant habit. Most of the genotypes grown are of local types. However, recently 'Thar Pragati' has been identified for cultivation by ICAR-CIAH, Bikaner.

Thar Pragati: This variety has spreading growth habit, thick stem, dense foliage and drooping branches. Fruit ripens in 60 days from fruit set. It is dwarf, early precocious bearer (bearing in 3rd year), drought tolerant and suitable for high density planting. It is suitable for table and processing purpose.

Nutraceutical value: *Phalsa* has been found to be a very good source of anthocyanin, a strong antioxidant. The mean value of anthocyanin content in *phalsa* was noted to be 10.18 mg/100g.

Uses: Its fruits are eaten as fresh. The fruits are highly perishable and are used in preparation of squash and juice. Ripe fruits are acidic in taste and rich source of vitamins A and C. Its medicinal properties are known since vedic times. Its fruits have cooling effect. Fruits are good source of carbohydrate, proteins, minerals and vitamins. Processed products like jam, squash and pickle can also be prepared from *phalsa* fruits. Bark of plants is used during preparation of jaggery for improvement of the quality. Pruned *phalsa* canes/shoots can be utilized for making baskets to transport fruit and vegetables to distant market.

4. *Karonda* (*Carissa carandus*)

It is one of the few fruits indigenous to India while 30 species of genus *Carissa* have been reported; many species are found growing wild in India while other species came from Malaysia and South Africa. It is cultivated throughout India in tropical and sub-tropical areas. In India *Carissa* are found growing most widely in plains and hills and grow wild in Deccan Peninsula, Maharashtra along the west coast, parts of Gujarat, Punjab, lower ranges of J & K, U.P., Uttaranchal and Mount Abu (Rajasthan). It also cultivated in other countries like Bangladesh, South Africa, U.S.A., Denmark, Ghana, Israel and Pakistan. In *karonda* plants, thorns are found. It is most suitable fruits for dry land horticulture. *Karonda* is generally grown on the boundary of orchard, farm, fields as bio-fencing. There is no regular orchard. *Karonda* fruits are mainly used for pickle and jelly preparation.

Varieties :

On the basis of fruit colour, the cultivars of *Karonda* can be classified as: (i) Green fruited, (ii) Pink fruited and (iii) White fruited. There is a quite resemblance in the shape and size of their fruits. However, there is a tremendous scope for improvement using selection force and vegetative method of propagation. A promising variety of *Karonda* 'Thar Kamal' have been identified at CHES, Godhra which are red colour fruit type and high yield potential.

Fast growing, drought tolerance and high yielding genotypes should be identified. More emphasis is needed on its processed products. It is susceptible to frost; hence, frost tolerance types should be identified for arid regions.

Thar Kamal : The variety is developed through selection from existing germplasm. Plant has semi-spreading growth habit, thick trunk, evergreen, dense foliage and drooping branches. Flowering start, in 3rd year, regular bearer, ripens (55-56 days from fruit set) in the month of June and recorded 4.97 g average fruit weight, 93.64% pulp and 9.54°Brix TSS, 0.64% acidity, 30.41 mg/100g vitamin C. Fruit yield 13.00 kg/plant (9th year). It is suitable for processing purpose.

Maru Gaurav : This variety has been identified at ICAR-CAZRI, Jodhpur. Average fruit weight is 3.74 grams, while TSS, acidity, Vitamin C and pulp content has been reported to be 9.4 %, 2.8 %, 35.88/ g 100-1 g and 88.5%, respectively.

Nutraceutical value: Studies at ICAR-CIAH, Bikaner has shown that in red and green type *karonda*, the values of anthocyanin, which is widely hailed as highly beneficial health protective compounds, were 3.85 and 0.35 mg/100g, respectively.

Uses: The fruits are used for making jam, jelly, pickles etc.

5. *Pilu* (*Salvadora* sp.)

It is a drought hardy tree and generally found in saline belts. *Salvadora* is an underutilized tree of arid region having multiple uses. The leaves are eaten by camel. There are two species commonly found in arid region i.e. *S. persica*, *S. oleoides*. It is multiplied through seeds and root suckers. There is no systematic plantation and its seed oil is very important for industrial uses.

Varieties: Great deal of variability in fruit shape, size and color are found due to seed propagation. There are no identified varieties of *pilu*; however, in nature two distinct types viz., red and green fruited types are found.

Table 5: Comparison of antioxidant properties of green and red fruited genotypes of *pilu* (mean values).

S. No.	Attributes	Red fruited	Green fruited
1	TSS (° Brix)	22.9b*	25.3a*
2	Ascorbic acid (mg/ 100g)	29.0a	18.2b
3	Total polyphenols (mg/100g)	619.7a	351.4b
4	Flavanol (mg/100g)	42.5a	36.4b
5	Flavonoid (mg/100g)	118.9a	93.5b
6	<i>o</i> -dihydric phenol (mg/100g)	27.35a	26.6a
7	Total AOX activity (CUPRAC; mMTE/100g)	10.38a	7.82b
8	Total AOX activity (FRAP; mMTE/100g)	8.31a	4.95b
9	DPPH inhibition (%)	88.40a	71.66b

*Row values followed by the same letter are not significantly different.

Nutraceutical value: Research carried out at ICAR-CIAH, Bikaner has revealed that red fruited one is richer in terms of different antioxidants at horticultural maturity.

Uses: This plant is gaining phenomenal significance for its oil rich seeds containing 40-50% non-edible fats of industrial use. Fruits are used for making juice and drinks. Fruits mature during summer season. *Pilu* is an underutilized fruit and can be exploited. It is suitable trees for farming system in arid region especially with pasture/grasses. It is found in the states of Gujarat, Haryana, Punjab, U.P., Rajasthan and M.P. with estimated annual seed production of 47,000 tonne having potential for 15,000 tonnes oil (Singh and Tewari, 1994).

6. Wood apple (*Feronia limonia*)

Wood apple (*Feronia limonia* Linn. Swingle), syn. *Limonia acidissima* L. *Feronia elephantum* Correa, *Schinus limonia* L. belongs to family Rutaceae. Wood apple is also called *kainth*, elephant apple, monkey fruit, curd fruit, *kathabel* and others name in India.

The wood apple is native to India and common in the wild form in dry plains of India and Ceylon. It is also found growing throughout South East Asia, in Northern Malaya and on Penang Island. In India, the fruit was traditionally a "Poor man's food" until processing techniques were developed in the mid-1950's. It occurs, wild or cultivated, up to an elevation of 1500 ft, in Western Himalayas, but more common in the Deccan; Thane and Chandrapur districts of Maharashtra. It is also reported to occur in parts of Hazaribagh, Palamau and Chhota Nagpur in Jharkhand, in forest of Vidhyan hills of Uttar Pradesh and Chattishgarh. It is often cultivated on borders of fields and as a roadside tree near villages and sometimes planted as orchards. There are no regular plantations however; stray plants along the border of fields, roads, railway lines and banks of the river are the common places where the plants are found.

Varieties: The plants growing so far are of seed origin and found to have lot of variability 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 fruit. There are two types of wood apple, one with fruit larger and

sweeter than the other and states that the ripe fruit pulp contains 2.3 per cent acid and 7.25 per cent sugars. Fruit is much used in India as a liver and cardiac tonic, and when unripe, as a means of halting diarrhea and dysentery and effective treatment for hiccup, sore throat and diseases of the gums. The pulp is poultice on to bites and stings of venomous insects as is the powdered rind. Juice of young leaves is mixed with milk and sugar candy and given as a remedy for biliousness and intestinal troubles of children. The powdered gum, mixed with honey, is given to overcome dysentery and diarrhea in children. Oil derived from the crushed leaves is applied on itch and the leaf decoction is given to children as an aid to digestion. Leaves, bark, roots and fruit pulp are used against snakebite. The leaves are aromatic, carminative and astringent.

Uses: The pulp constitutes 55-56 percent of the whole fruit. The pectin content of the pulp is 3-5 per cent (16% yields on dry weight basis). The seed contains bland, non-bitter oil with high unsaturated fatty acids. The fruits are so hard that rind be cracked with a hammer. The scooped-out pulp, though sticky, is eaten raw with or without sugar, or is blended with coconut milk and palm-sugar syrup and drunk as a beverage, or frozen as an ice cream. It is also used in chutneys and for making jelly and jam (Gopalan *et al.*, 1971).

7. Jharber (*Ziziphus nummularia*)

This thorny shrub is locally known as *Jharber* and occurs throughout North-west India. Apart from its edible fruits and fodder value, different plant parts of it have medicinal value. This is one of the multipurpose shrubs of arid zone.

Uses: Ripe fruits are eaten as fresh and stored as dried fruits. Dried fruits used in making sweets and drinks, while seeds are eaten in scarcity period.

8. Kumat (*Acacia senegal*)

It is a much-branched thorny tree with pale smooth bark. It founds on hillsides and stabilized sand dunes. It is hardy species surviving under harsh edapho-climatic conditions. It is an ideal species for agro forestry systems.

Uses: It is used in *Pachkutta*, a traditional vegetable delicacy of arid regions. It yields the true

gum Arabic, an important commercial product and used in pharmaceuticals. Apart from gum production, its seeds are used as food; leaves and pods as fodder, and wood for fuel wood and charcoal preparation.

9. *Gangana (Grewia tenax)*

This winter deciduous shrub naturally occurs in buried pediments, hills and pediplains in arid region. Deep sandy loam is best soil for species, however it can grow in very shallow, skeletal, gravelly or clay soils. It is extremely drought hardy and tolerates frost. Fruits (drupe) are smooth, shining, yellow orange to red when mature. Fruit production in natural stands varies very much.

Uses: Ripe fruits are eaten as fresh. It also provides excellent leaf fodder.

10. *Khirni (Manilkara hexandra Roxb.)*

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, which is 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.

Uses: Bark, fresh fruits and extracted seeds have high nutritional and medicinal value. The tree is very well known to rural folk since ages in India.

11. *Mahua (Madhuca indica)*

It is a deciduous tree that grows widely under dry climatic conditions. It is very hardy and thrives well on rocky, gravelly, saline and sodic soils, even in pockets of soil between crevices of barren rock.

It is one of those multipurpose forest tree species that provide an answer for the three major Fs i.e. food, fodder and fuel. *Mahua* is a tree valued for its fruit, seeds, which are the largest source of natural hard fat commercially known as *mahua* butter or *mowrah* butter.

Varieties: A semi-spreading variety 'Thar Madhu' has been identified by ICAR-CIAH, Bikaner, which starts bearing in 5th year. Yield has been reported to be 20 kg fruits per plant. Yield of dry flower: 6.30 kg per plant. Fruit ripens in 90-105 days from fruit set.

Uses: Fruits are eaten as raw or cooked. The fruit pulp may be utilized as source of sugar, whereas the dry husk makes a good source of alcoholic fermentation. Seeds are good source of oil. The oil obtained from kernel which is said to be useful for heart patients is used for edible purpose and permitted for preparation of vegetable oil. Amount of oil obtained from seeds of the fruit is higher than many oil seed crops and oil-bearing trees. In *Mahua* oil is used in manufacture of soap, lubricating grease, fatty alcohols and candles. Flowers of the plant are edible. The corolla commonly called as *mahua* flowers is a rich source of sugar containing appreciable amount of vitamins and minerals (Singh and Singh, 2005). The flowers are also used in preparation of distilled liquor, portable spirits, vinegar and feed for livestock (Ghosh, 2015).

12. *Chironji (Buchnanian lanzan)*

It is a deciduous tree which produces edible seeds. These almond-flavoured seeds are used as a cooking spice primarily in India. It is cultivated across India, primarily in the northwest. After the hard shell is cracked, the stubby seed within is as soft as a pine nut. The *chironji* seed is lentil-sized, is slightly flattened and has an almond-like flavour. Though they can be eaten and used raw they are often toasted or roasted before use, as this intensifies the flavour.

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, fruit ripens in 50-65 days from fruit set. It is comparatively dwarf, precocious bearer (4th year) and suitable for

high density planting. 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.

Uses: The *chironji* seeds are commonly used in sweets in India. However, they are also ground into powders for thickening savory sauces and flavoring batters, and stewed into rich, meaty kormas. Seeds are also used in the Ayurveda and Unani systems of medicine.

13. Mulberry (*Morus spp.*)

Mulberry grows throughout India but more extensive in Karnataka particularly Mysore especially for sericulture. In India, there are many species, of which *Morus alba* and *M. indica* are fully domesticated while other important species are *M. laevigata*, *M. rubra*, *M. nigra* and *M. serrata* (Vijayan *et al.*, 2011). Mulberry is a fast growing deciduous woody perennial plant, wide-spreading, round-topped, trunk attaining 60 cm in diameter. It has a deep root system. All three mulberry species (*M. alba*, *M. rubra* and *M. nigra*) are deciduous trees of varying sizes. White mulberries can grow to 24 m and are the most variable in form, including drooping and pyramidal shapes. In the South on rich soils the red mulberry can reach 20 m in height. The black mulberry is the smallest of the three, sometimes growing to 10 m in height, but it tends to be a bush if not trained when it is young. The species vary greatly in longevity. Red mulberry trees rarely live more than 75 years, while black mulberries have been known to bear fruit for hundreds of years. The mulberry makes an attractive tree which bears fruit while still small and young (Krishna *et al.*, 2018).

Uses: The ripe fruit of mulberry is highly appreciated for its delicious taste which is consumed fresh or after extraction of juice. Immature fruits are used for chutney preparation. Mulberry fruit is used to treat weakness, dizziness, tinnitus, fatigue, anemia, and incontinence (Krishna and Chauhan, 2015).

Varieties: Huge diversity exists in available germplasm pool of mulberry in India. Mulberry being perennial and out breeding tree, exhibit high degree of heterozygosis. Till recently, no variety was developed in mulberry for commercial fruit

production. However promising selections of mulberry, intended for commercial fruit production, have been identified at ICAR-Central Institute for Arid Horticulture, Bikaner, Rajasthan *viz.*, Thar Lohit (red fruited) and Thar Harit (white fruited). Thar Lohit was found to be earliest with respect to maturity period. It took 30-35 days to mature. Upon quality assessment, 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.

14. Cactus pear (*Opuntia ficus india L.*)

Cactus pear (*Opuntia ficus india* (L) Mill.) is known as 'Prickly pear' or Cactus fig or Tuna. It belongs to family Cactaceae. Genus *Opuntia* has nearly 300 species, out of them, 12 species are grown for fruits, vegetable and fodder purpose. 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 human and livestock. It is a most suitable plant for semi arid and arid regions. In India, it is found in wild state and underutilized fruit. However, it is a National Crop of Mexico. The cactus pear is commercially cultivated in countries like USA, Israel, Chile, Peru, Brazil, Bolivia, Argentina, Italy, Tunisia, Middle East and South Africa. It is a xerophytic spiny or spineless plant. It has shallow, fibrous root system. Roots are developed when the areoles are in contact with soils. The plants have thick succulent stem called 'cladodes'. These cladodes or cactus stems have numerous areoles which function like meristematic buds. The buds develop in to new cladodes and fruits (areal parts) and roots (underground parts) with passage of time (Wessals, 1998). The thornless type cactus pear has introduced from Texas, USA and Israel.

Varieties: 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 agroclimate of western Maharashtra and it is reported that some clones also produced fruits (Meghwal and Singh,

Uses

Uses	Forms
Fresh fruit	Fruits and fruit peel fresh
Fruit products	Dried, canned, juice, pulp, alcoholic, beverages, jam, syrup,
Stems	Jellies, pastries, liquid sweetener, seed oil. Fresh processed in brine or vinegar, precooked, frozen, pectin.
Forage	Fodder stems, fruits, seeds and forage shrub
Energy	Biogas (stems, fruits); ethanol (stems, fruits) and firewood.
Medicine	Diarrhoea (stems), diuretic (flower, roots), amoebic dysentery (flowers), diabetes mellitus (stems), hyperlipidemy (stems), obesity (fibres) and anti-inflammatory (stems).
Cosmetics	Shampoo, cream, soaps, astringent and body lotions (stems)
Eco-conservation	Soil binders, hedge, fence, mulching material, windbreak (plants, stems) and organic manure.
Other uses	Adhesives and gum, fibers for handicrafts, paper (stems), dyes (fruits, rearing of <i>Dactylopius coccus</i> on stem), mucilages for food industry (stems), anti-transparent (stems) and ornamental plant.

2016). In 1991, 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 production.

15. Marula nut (*Sclerocarya birrea* subsp. *caffra*)

Marula nut fruit plant (*Sclerocarya birrea* subsp. *caffra*) is a member of Family Anacardiaceae. The plant is tall, dioecious, deciduous tree, which grows naturally in northern South Africa and parts of eastern Botswana. In southern Africa, marula trees are one of the most highly valued indigenous plant species. It has several medicinal properties. It is cultivated for fresh fruit in Arava valley, Israel, where annual average rainfall is about 100 mm and dry climate. In the experimental plots many branches died due to winter temperatures of -7 degrees Celsius. In the spring, however, all plants resumed their growth from the lower parts of the stem. In northern Sotho, marula trees are not cut down when land is cleared for planting and cultivation because of its high value. Marula tree bears male and female flowers on separately. It is a dioecious fruit tree and flowering takes place during summer season. Fruits are ripened during September-October month. The fruit yield depends on growing site, age of tree and management practices employed. Marula fruits

abscise when mature but ripen only a few days later. In western arid part of India, it has introduced from Israel and evaluated for growth and development of plant. It is a fast growing fruit tree but it is susceptible to low temperature and frost during winter season in arid region. Marula fruit is very sweet, juicy and aromatic. It looks like a small yellow plum. It is eaten fresh and the flesh has extremely high vitamin C content. The TSS of fruit is 13.2° brix at full ripen stage.

Uses: Besides its consumption as fresh fruits, it is used to prepare jam, juices and alcoholic beverages. Inside the flesh, one or two small tasty nuts are available which are rich in protein. Its seed oil is used as a skin cosmetic.

Value addition: If exploited properly, these underutilized fruits have the potential of transforming the economy of rural and tribal areas because such crops are, usually, of explicit quality with great nutritional, medicinal, organoleptic, economic and traditional importance; however, they are available for a very short period during the growing season. Therefore, the value added products will definitely help to provide taste throughout the year if processed during the season. It will not only help the growers to get good returns for these under-utilized wild fruits but also provide nutritionally and medicinally rich value added products for the consumers. Some underutilized fruits, though they are not utilized as table fruit (ker, lasoda, Karonda, tamarind, wood apple) because high acidity, strong astringent taste and also difficulty in eating can be converted into value added processed products like pickles, chutney,

Table 6: Potential value added products from different underutilised fruits.

Fruits	Processed / Value added products
<i>Ker</i>	Dehydrated fruits, pickle
<i>Lasoda</i>	Dehydrated fruits, pickle
Mulberry	RTS, Squash, Jam, vinegar
<i>Jharber</i>	Dehydrated fruits, Dry fruit powder as acidulant
<i>Karonda</i>	Jelly, pickle, candy, chutney
Cactus pear	Pickle
<i>Jangal jalebi</i>	Juice, various home preparation
<i>Chirounjee</i>	Dried nut and various nut based products
<i>Mahua</i>	Juice, squash, nectar, RTS from fresh flower, dehydrated flowers and various home scale products, Jam, juice etc. from ripe fruit
<i>Phalsa</i>	Juice, syrup and other fruit beverages
Tamarind	Kernel powder, Juice concentrate, Pulp powder, Pickle, jam, syrup, candy
<i>Jamun</i>	Vinegar, cider, syrup, Nectar, RTS
Woodapple	Chutney, pickle, jelly, fruit beverages
<i>Pilu</i>	RTS, nectar, squash

squash, jam, dehydrated products etc.. There is good demand not only in domestic market but also in international trade for new food products, especially, which are highly nutritious and delicately flavoured. Some processed fruits like tamarind, ker, lasoda and khejri products are now being marketed in those parts of the world where Asian particularly Indians are settling in large population.

Constraints in expansion of area under cultivation of underutilized fruits

Exploitation underutilized fruits is delimited by a gamut of factors such as technical, socio-economic and institutional. The main constraints are as followed;

- Poor awareness about the nutritional and medicinal value of underutilized fruit crops.
- Less emphasis in researches for exploitation of potential underutilized fruits.
- Lack of standardized propagation techniques in many such fruits and non-availability of quality planting materials (seed and vegetative parts).
- Limited application of modern cultivation practices e.g. negligible use of innovative and novel technologies such as biotechnology, plasticulture for enhancement of productivity.
- Lack of proper transportation facilities for an efficient supply of production inputs and timely disposal of produced in the market.
- Lack of knowledge about suitable postharvest management practices.

- Under-developed marketing channels and infrastructure like storage facilities.
- Non-competitive prices of produce of underutilized fruits.
- Inadequate extension services for promotion of cultivation underutilized fruits.
- Negligible set up of agro-industrial units.

Strategies for the development of arid underutilized horticultural crops

- Creation of awareness about the nutritional importance of unexploited fruits through organization of special awareness camps/campaigns, exhibition, etc., at micro and macro level, use of mass media like radio, TV, newspaper and distribution of other printed literature.
- Emphasis on sustainable collection and use of various fruits from forests and domestication of potential wild species for avoiding over-exploitation from natural sources.
- More crop-specific systematic research and development efforts entailing conservation of genetics resources, improvement, production technology advancement, postharvest management, value addition etc., keeping in view the agro-climatic suitability of the region.
- Independent tailor-made research for crops important for subsistence farming and those exhibiting potential to become commodity crops.

- Development of trait-specific varieties from the available gene pool to cater the intended demand.
- Mass multiplication of planting materials and their distribution.
- Increased focus to document indigenous knowledge through ethno-botanical studies to tap multipurpose uses of such crops.
- Emphasis on development of processing units in rural areas.
- Expansion of infrastructure facilities with priority on market development, transport and communication.
- Promotion of export oriented production programmes of targeted crops.

A number of underutilized fruits are available in arid parts of the country. The less known fruit crops should be popularised and improved cultural practices should be developed for different agro-climatic regions. These plants are not only yields fruits but also provide firewood, leaf fodder and serve as wind breaks in arid regions. Owing to its multiple uses, it can be used in different farming systems to meet the basic needs of local inhabitants.

Thus, it can be concluded that more attention is needed on exploitation of genetic resources of underutilized fruits. There is a tremendous scope of underutilized fruits cultivation in water scarce areas of the country. Under drought conditions, using underutilized plants in horti-pasture and agro-horticultural system are suitable to fulfil the local demand of food, fodder and fuel besides several products of economic uses. The genetic resources may be utilized for crop improvement as a source of resistance, hardiness and vigour. The post harvest management of underutilized fruits is essential for value addition.

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