



Underutilized Fruits Research in Arid Regions: A Review

P.R. Meghwal* and Akath Singh

ICAR-Central Arid Zone Research Institute, Jodhpur 342 003, India

Received: June 2015

Abstract: The hot arid regions of India cover 31.7 Mha area spread in 7 states with major area in states of Rajasthan and Gujarat. These regions are characterized by low and erratic rainfall with high coefficient of variation and harsh climatic conditions. In spite of climatic and other constraints, these regions are suitable for growing of many fruit species like *ber*, pomegranate, *aonla*, datepalm and citrus, etc. which are grown commercially. Besides these fruit crops some underutilized fruits crops mostly indigenous ones are becoming popular in arid regions on account of their diversified uses. Underutilized crops could be considered in these areas for integration in existing farming system as these crops require less inputs and can sustain the harsh climatic conditions. There are around 30 plant species in arid zone known for their edible uses out of which some 20 plant species are known for their edible fruits or as vegetables viz., *kair* (*Capparis decidua*), *lasora* (*Cordia myxa*), *jhar ber* (*Ziziphus nummularia*), *pilu* (*Salvadora oleoides*), *khejri* (*Prosopis cineraria*), *phalsa* (*Grewia subinaequalis*), *bael* (*Aegle marmelos*), *karonda* (*Carissa carandas*), fig (*Ficus carica*) and prickly pear (*Opuntia ficus-indica*) etc. These underutilized fruits have many advantages in terms of ease in growing, hardy nature and good yield even under extreme weather conditions. These crops have their own history of consumption because, local people are well aware about their nutritional and medicinal values. Thus, these crops have the potential to provide great nutritional and social benefits and it is increasingly advised that they are identified, researched and promoted in the way similar to the other commercial fruit crops. This paper reviews the work done on collection, evaluation and conservation of germplasm, ethnobotanical values, improvement, propagation, agrotechniques, post harvest management, value addition, problems encountered and researchable issues pertaining to underutilized fruit crops in arid region.

Key words: Underutilized fruits, arid region, production potential, extreme weather, researchable issues and future strategies.

The hot arid regions of India are spread 31.7 Mha area in the states of Rajasthan, Gujarat, Punjab, Haryana, Karnataka and Andhra Pradesh. Rajasthan occupies the major area (61%) spread over 12 districts in north-western parts. The region receives annual rainfall between 100-500 mm with high coefficient of variations (40-70%). Low and erratic rainfall coupled with extreme weather results in complete or partial crop failure. Frequent droughts, wind erosion, covering of fertile land due to shifting of sand dunes are common features of arid regions. Underutilized fruit plants that have some special adaptive features like deep tap root systems, leaf shedding in summer, water binding mechanism, wax coating, hairiness, sunken and covered stomata in leaves, tolerance capacity to salinity and

alkalinity, synchronization of flowering and fruiting during rainy season or at maximum water availability offer scope in arid regions. Underutilized crops are defined as 'species' with under-exploited potential for contributing to food security, health (nutritional/medicinal), income generation and environmental services (Mitra *et al.*, 2011). In the arid regions of Rajasthan alone, there are about 29.64% area under wasteland and 16.96% under culturable wastelands of different kinds viz. sand dunes, saline, ravines soils, which are not suitable for cultivation of high input demanding crops. Such areas may be exploited for growing potential underutilized fruits to diversify production systems to meet the food and nutritional demand of increasing population. As monocropping is non-remunerative and risky under changing climatic conditions of the region, it may be possible to exploit untapped

*E-mail: pr.meghwal@icar.gov.in

potential of the region through specialized crops. Integration of indigenous underutilized fruits could be one of the appropriate facets to enhance overall horticultural production in the region. Arid zone vegetation comprises a wide range of edible fruit bearing and food producing species. Many of underutilized fruit crops not only fulfill the requirement as dessert fruit but also for culinary and medicinal purposes and local people are well aware about their nutritional and medicinal properties. There are around 30 plant species in arid zone known for their edible uses either table purpose or as vegetables. Important among these are listed in Table 1.

Kair

Kair is a shrub of family Capparaceae which comprises about 30 genera and 600 species. It occurs in tropical and warm temperate region (Vyas *et al.*, 2009). In India, about 26 species are reported (Heywood, 1978) which are distributed in arid and semi-arid tracts. The species play ecological roles in providing vegetative cover, improve soil fertility, prevent soil erosion and promote biodiversity besides its economic significance (Shankarnarayan *et al.*, 1987). It is also considered as a potential ethnobotanical weather predictor and livelihood security shrub of the arid region (Singh and Singh, 2011). *Kair* is found growing along farm boundaries, *orans*, *gochar* and wasteland and has ability to survive

in various habitats. Rich variability with respect to plant types, canopy, flowering and fruiting has been observed *in-situ* in natural population and efforts were made to conserve the collected variability *ex-situ* (Mahla and Singh, 2013). It has good soil binding capacity, a fair tolerance to salinity and alkalinity and can help to improve soil fertility. Its xerophytic qualities make it suitable for cultivation on large scale, especially to combat soil and wind erosion on sand dunes and sandy wastelands. Gupta *et al.* (1989) reported ten fold increase in organic carbon and two fold increase in available NPK in soils under 20 years old *kair* plantation.

In addition to socio-economic and ecological advantage, it has numerous medicinal properties as its different plant parts have pharmacological activities like hypercholesterolemic, anti-inflammatory and analgesic, anti-diabetic, anti-microbial, antiplaquer, antihypertensive, antihelmintic and purgative activities (Satyanarayan *et al.*, 2008).

Multiplication through root suckers is considered as natural propagation of *kair* (Mallik *et al.*, 2010). However, not much success has been achieved when such suckers were separated from mother plants and attempted to establish at another site (Singh *et al.*, 2005). Seed germination is quite good but post germination mortality hinders large scale multiplication. The germination of seed started

Table 1. Suitable underutilized fruits for western Rajasthan

Scientific name	Common/ local name	Family	Distribution
<i>Capparis decidua</i>	<i>Kair/ker</i>	Capparaceae	Hot and sandy desert, Jodhpur, Bikaner, Pali, Nagaur
<i>Salvadora oleoides</i>	<i>Meetha jal</i>	Salvadoraceae	Jodhpur, Barmer, Jalore, Bikaner, Jaisalmer, Churu, Nagaur
<i>Cordia myxa</i>	<i>Lasora</i>	Boraginaceae	Jodhpur, Barmer, Pali and rangelands of arid and semi-arid ecosystem
<i>Ziziphus nummularia</i>	<i>Jhar ber</i>	Rhamnaceae	Arid and semi-arid regions of Rajasthan
<i>Prosopis cineraria</i>	<i>Khejri</i>	Mimosaceae	Arid and semi-arid regions of Rajasthan
<i>Carissa carandas</i>	<i>Karonda</i>	Apocynaceae	Jodhpur, Jaipur, Pali, Sirohi, Udaipur, Chittor, Ajmer, Bhilwara etc.
<i>Aegle marmelos</i>	<i>Bael</i>	Rutaceae	Arid and semi-arid regions of Rajasthan
<i>Opuntia ficus-indica</i>	Prickly pear	Cactaceae	Wild species <i>O. elatior</i> found growing at selected places through out Rajasthan, however, the <i>O. ficus-indica</i> is of recently introduced cultivated species which is being tried at Jodhpur, Bikaner and Kutch Bhuj region of Gujarat
<i>Ficus carica</i>	Common fig	Moraceae	It is grown in Udaipur, Ajmer and in kitchen garden and garden through out Rajasthan except extreme arid district like Bikaner, Barmer, Jaisalmer etc.
<i>Citrus latifolia</i>	Persian lime	Rutaceae	Ajmer, Jodhpur, Jaipur, Pali, etc.

after 10 days of sowing and continued upto 27 days with mean germination of 72.4% while field survival after one year of planting ranged from 36.1-64.3% (Mahla *et al.*, 2012) in different accessions. Vegetative propagation is essential for producing true to type plants. Planting of hard wood cuttings during July-August showed significantly higher rooting irrespective of rooting hormone treatment (Meghwal and Vashishtha, 1998). Propagation through hard wood cutting using quick dip with indole butyric acid (1000 ppm) in the month of July resulted in poor success in rooting (Vashishtha, 1987). Micropropagation could be an effective means of mass propagation in *kair*. Deora and Shekhawat (1995) succeeded in getting multiple shoots from nodal explants on Murashige and Skoog (MS) medium supplemented with 0.1 mg L⁻¹ NAA + 5 mg L⁻¹ BAP. Tyagi and Kothari (1997) also reported in vitro clonal propagation of *kair* using nodal explants from mature trees as well as seedling derived cotyledonary node, cotyledon and hypocotyl explants. M.S. medium enriched with 5 mg L⁻¹ BAP showed maximum shoot proliferation from nodal explants of seedlings and mature plants. Maximum rooting occurred on half strength M.S. medium supplemented with 1 mg L⁻¹ IBA.

The economic importance of this species is in its tiny fruits. The green immature fruits are highly valued for preparation of pickle and vegetables either alone or in combination with *khejri* pods etc. However, the fruits at this stage are astringent due to presence of tannins and other phenolic compounds, which can be removed by certain technique (Meghwal

and Azam, 2007). The immature fruits are rich in carbohydrates, protein and mineral elements (Chouhan *et al.*, 1986). Fifteen natural compounds were identified and isolated from *kair* fruits (Rai, 1987). The fruits were also found to be rich in dietary fibre (Agarwal and Chouhan, 1988). Harvesting of *kair* fruits at right stage of maturity is very important. The fruits harvested at 7-10 days after fruit set with 5-8 mm diameter during March-April is ideal (Meghwal, 2002). The cured fruits can be prepared into vegetable curry, pickle or sun dried for use in the off season. Properly sun dried immature fruits of *kair* are sold in the urban retail market @ Rs. 800-1200 kg⁻¹ depending upon the size. The smallest sized fruits fetch highest price. Recently sprouted shoots are relished by camel and goat during spring summer season (Meghwal and Tewari, 2002).

Lasora

Locally known as *Gonda/Lasora/lehsua* (*Cordia myxa* L.), belongs to family Boraginaceae and is grown all over India except high hills. It has great capacity to tolerate drought and hence quite widespread in arid and semi-arid regions of north India. Being a multipurpose plant, it has long been associated with health, nutrition and other diversified uses. The immature fruits of *gonda* are used as vegetable, pickled with raw mango and can be dehydrated for future use. The fruits and other plant parts are used in curing various ailments viz. skin diseases, dropsy, dysentery, dyspepsia, cholera and headache etc. The fruit contains about 80% pulp; while the pulp contains per 100g dry weight: ash 6.7 g, crude protein 8.32 g, lipid



Fig. 1. Defoliation in *Lasora* and mulching in tree basin.

2.2 g, crude fibre 25.7 g, carbohydrates 57.08 g and 281.4 k calori (Aberoumand, 2011). Pareek and Sharma (1993) also reported *lasora* fruits to be rich source of carbohydrates, phosphorus and ascorbic acid (40 mg/100 g). The nutritive value of forage per 100 g dry matter: crude protein 15 g, crude fibre 20 g, ash 14 g, crude fat, 6 g, N free extract 47 g, Ca 2.5 g, P 0.3 g (Oudhia, 2007). The fruits are also rich source of phenolic compounds which have antioxidant properties. Aberoumand (2011) reported good amount of total phenolics (402 mg/100 g) in the fruits of *lasora*. Nagar *et al.* (2013) recorded high genotypic coefficient of variation for fruits per cluster, fruit size, fruit weight and TSS with high heritability and genetic advance. Trees are planted at field boundaries as wind break and shelter belt to check the movement of sand because of dense and leathery foliage which are equally important for non-tangible benefits. *Cordia myxa* can be used in landscape gardening, afforestation and reforestation in semi-arid and arid areas as well. *Cordia myxa* requires certain period of dormancy in winter season therefore, the leaf should be removed either manually or through defoliant chemical in the month of December-January to obtain early and uniform fruiting. The leaf biomass obtained may be used for mulching or compost preparations. The addition of chopped leaves of *C. myxa* to nematode infested soil increased the growth of aubergines and reduced the populations of plant parasitic nematodes up to 80.5% (Haseeb *et al.*, 1984).

In view of its economic importance and drought hardy nature, work on its survey, collection, evaluation and improvement were initiated in the year 2000-2001 at CAZRI, Jodhpur.

Twelve germplasm accessions were collected during 2000-2004 from different parts of the country and evaluated for improvement by selection. Different accessions showed wide variation in the fruit size, shape, yield, and stone: pulp ratio (Table 2). Long term evaluation of collected germplasm resulted in identification of four high yielding genotypes (CAZRI G-2011, CAZRI G-2012, CAZRI G-2021 and CAZRI G-2025) based on yield, bold fruit size and high pulp content (Meghwal *et al.*, 2014a). Budded plants of these genotypes were also planted at farmers' field in Barmer district under rainfed condition with supplementary irrigation from harvested rain water from farm pond. The farmer got fruit yield from these plants in the second year and in third year it ranged from 5-15 kg per plant. Seed treatment with GA₃ (250 ppm for 2 hours) improved germination to 50% as compared to only 10% in control. However, the highest germination was recorded when this treatment was preceded by mechanical scarification (Meghwal, 2007). Evaluation of different genotypes on three types of rootstocks revealed small fruited *gonda* as the best rootstock for commercial big fruited *gonda* irrespective of genotypes (Meghwal *et al.*, 2014b). Maximum success was observed when budding was done on 15th August (95%) on *gonda* rootstock, though it could be done till 15th September with equal success.

Agrotechnique has been developed to take early crop by defoliation during first week of January and irrigation scheduling. Regular irrigation is required during establishment phase (3-4 years) after which no irrigation may be given during monsoon and winter season except occasional life saving irrigation. The

Table 2. Fruit characteristics and yield of different accessions of *lasora* (*Cordia myxa*)

Accession No.	Mean bunch weight (g)	No. of fruits per bunch	Mean fruit weight (g)	Stone: Pulp ratio	Mean fruit yield at 8 years (kg plant ⁻¹)
CAZRI G-2011	60.00	8.20	8.00	1:6	6.2
CAZRI G-2012	62.00	10.00	7.80	1:5.6	21.0
CAZRI G-2013	110.00	7.60	9.50	1:5.2	7.8
CAZRI G-2014	28.65	4.62	7.91	1:6	4.1
CAZRI G-2021	137.40	14.80	9.00	1:6	13.8
CAZRI G-2022	57.40	8.40	5.81	1:5	2.8
CAZRI G-2023	58.63	8.90	7.63	1:6	3.1
CAZRI G-2025	61.50	14.00	10.50	1:6.5	28.0
CAZRI G-2026	60.00	10.00	8.50	1:5.6	4.8

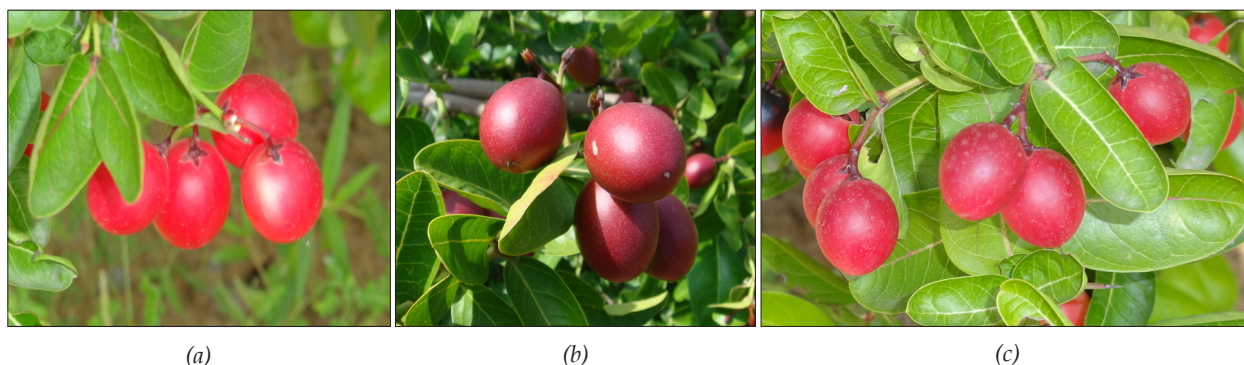


Fig. 2. High yielding varieties of karonda (a)-CZK-2022, (b)-CZK-2011, (c)-CZK-2031.

natural leaf fall occurs during February-March, however by withholding irrigation during post monsoon period, it starts early during in the month of January. The natural leaf fall may also be supplemented with manual defoliation to complete the process. Chemical defoliation may also be done with foliar spray of 1000 ppm of 2-chloroethyle phosphonic acid during first week of January (Meghwal, 2013 unpublished data). The harvested leaves of each tree is spread in basin of the same tree (Fig. 1) and covered with thin layer of soil. This helps to conserve moisture besides bringing down the soil temperature. Manuring and irrigation are started from 15th February onwards with the rise in temperature. This ensures new growth and flowering which occur almost simultaneously. Regular irrigation is given from mid February to mid May or till fruit harvesting is completed. The fruits attain marketable maturity after 30-40 days of its setting. Mature green fruits are harvested before ripening. The fruits turn yellowish brown upon ripening which are harvested for extraction of seeds for raising nursery. The fully ripened fruits are very sweet (TSS 22-28 °Brix) and are relished by children in rural areas. However due to more content of mucilaginous substance, it lacks commercial value.

Karonda

Karonda (*Carissa carandas* L.) is an evergreen spiny shrub or a small tree which belongs to the family *Apocyanaceae*. It is considered as economic and popular protective live fence plant. If allowed to grow freely, it can reach to a height of 3 to 6 meters. It yields a heavy crop of attractive berry like fruits (10-40 kg plant⁻¹) which are edible and rich in iron, calcium, magnesium, phosphorus and vitamin C. It is native to India and also grown widely in South Africa and Malaysia. In India, it grows wild in states of Bihar, West Bengal, Uttar Pradesh, Uttarakhand, Maharashtra, Rajasthan and Southern India. Diversity in *karonda* has been reported in the north-western part of India especially in Mount Abu hills, Ghats and Khandala in Maharashtra (Mehra and Arora, 1982). This offers great deal of scope for improvement in *karonda* by selections (Joshi *et al.*, 1986). At Rahuri in Maharashtra, some promising types No. 13, 16, 12 and 3 have been identified (Karale *et al.*, 1990). It flowers from February to April and fruit mature during August-September and thus makes best use of monsoon rain and therefore, highly suitable for growing in arid regions. Looking to its suitability in arid areas, the work on germplasm collection, evaluation and characterization was

Table 3. Proposed varieties of karonda identified for release

Name of proposed variety	Breeding method	Important traits
CZK-2011	Selection	Fruit size-21.79 x 16.35 mm, elongated ovoid green with purple blush colored fruit, mean fruit weight-3.74 g, TSS-9.4%, acidity-2.82%, DM-12.85%, Vit. C-35.88 mg 100 ⁻¹ g
CZK-2022	Selection	Fruit size-22.47 x 19.14 mm, ovoid white with pink colored fruit, mean fruit weight-4.18 g, TSS-8.5%, acidity-2.14%, DM-12.77%, Vit. C-37.80 mg 100 ⁻¹ g
CZK-2031	Selection	Fruit size-22.66 x 19.57 mm, ovoid half white half pink colored fruit, mean fruit weight-5.01 g, TSS-8.7%, acidity-2.95%, DM-12.96%, Vit. C-37.4 mg 100 ⁻¹ g

initiated during 2000-2002. Seven germplasm accessions from different parts of Rajasthan, Gujarat and Uttarakhand and a released variety Pant Manohar were collected and evaluated for more than a decade.

Large deal of variation was recorded in plant height, canopy area, growth habit, precocity, morpho-physico-chemical characteristics of leaves, fruits and fruit yield (Meghwala *et al.*, 2012). Based on the performance of the germplasm over a period of eight years with respect to fruit yield and other desirable attributes, the accession Nos. CZK-2011, CZK-2022 and CZK-2031 could be recommended for cultivation in arid zone on account of their higher yield and bigger sized fruits. Subsequently these genotypes were identified for release as high yielding varieties (Singh *et al.*, 2014; Table 3; Fig. 2). Additionally three varieties viz. Pant Sudarshan, Pant Manohar and Pant Suvarna have been released from GBPUA&T, Pantnagar (Mishra, 2007) and one more variety Thar Kamal has been released from CIAH, Ghodhra centre (Singh *et al.*, 2013).

Khejri

Khejri (*Prosopis cineraria* L. Druce) is an important component of arid farming system which plays significant role in the economy of people of Indian Thar desert. This tree is well adapted to prevailing agro-climatic conditions of arid and semi-arid region. Owing to its multiple uses, atmospheric nitrogen fixing ability and suitability in agro forestry systems, it has been conserved in arable land since ages. Different parts of *khejri* plants have long been used by desert people for various purposes. Its highly nutritious leaves constitute important source of fodder for livestock while nutritious pods are valued as vegetable for human beings. The immature pods of *khejri* are edible and rich in crude protein (18%), carbohydrates (56%) and minerals such as phosphorus (0.4%), calcium (0.4%) and iron (0.2%) on dry weight basis (Duhan *et al.*, 1992) and are used as vegetables as fresh as well as after dehydration. The ripe dried pods having 9-14% crude protein and 6-16% sugar (Arya *et al.*, 1991) can be powdered and used in the preparation of bakery items such as biscuits and cookies. A survey of *khejri* in 12 arid districts of Rajasthan revealed wide ranging variability with respect to pod length, thickness, number and weight

of seeds, tenderness and nutritional value (Vishalnath *et al.*, 2000). Immense variability found in natural population offers scope for selection of desirable types which can be maintained by vegetative propagation method. Thornless canopy, higher green leaf and pod yield are desirable attributes. The pods should be long, thin, less fibrous and sweet in taste for vegetable purpose. Pareek (2002) observed diversity in pod characteristic such as taste (flat, bitter, acrid and sweet), tenderness (hard, semi-hard, less tender, tender), fibre content (fibrous, less fibrous and fibreless), color (green, light green), pod length, thickness, seed number, seed size, protein content and mineral constituents. Among these traits, sweet taste, long length, thin, tender pods green in color, and less fibrous ones are the desirable traits for culinary purpose. The trees having desirable pod characteristics may be identified from the natural population. However, particular desirable types may be lost forever due to uprooting of trees by wind storms, flood, other natural calamity, by natural death or by the attack of pest and diseases. Recently, the intensive survey of *khejri* population in the districts of Nagaur, Sikar, Jhunjhunu, Churu and Jodhpur have recorded mortality to the tune of 7-10% due to attack of insect pest *Acanthophorus serriticormis* and pathogen *Ganoderma lucidum* (Singh, 2007). Attempts have been made in the past to propagate *khejri* through micropropagation (Kakkar *et al.*, 1991) and air layering but those could not be commercially viable. Techniques have been developed to perpetuate desirable pod or any other character by budding *in situ* (Meghwala and Harsh, 2008). The main objective of budding in *khejri* is to identify the trees with desirable pod characteristics from natural stands and multiply them by budding on seedling rootstocks. CIAH, Bikaner has developed the variety Thar Shobha by adapting this technique. Survey of *khejri* germplasm for desirable pod types for culinary purpose resulted in identification of two superior types of plants having longer pods and thornless canopy (Anon., 2008). The selected plants were propagated clonally (through budding). Both the genotypes started flowering and fruiting in third year. Composition of leaves of budded *khejri* verses seedling of identical age revealed somewhat higher crude protein in budded *khejri* leaves as compared to seedlings

while it showed no appreciable differences in dry matter, moisture content, ash and organic matter content (Meghwal, 2009, unpublished data).

Bael

Bael (*Aegle marmelos* L.) a plant of Indian origin having tremendous therapeutic potential is not fully utilized. It belongs to family Rutaceae, to which belong all citrus fruits. The *bael* in India is known from prehistoric time and has been mentioned in the ancient system of medicine. Every part of the plant such as fruit, seed, bark, leaf, and root are important ingredients for several traditional formulations. Due to its curative properties, it is one of the most useful medicinal plants of India. The products obtained from *bael*, being highly nutritive and therapeutic value are getting popularized in Indian as well as international markets. It can be cultivated in wasteland as well as on unproductive land for upliftment of farmers (Sharma, 1997). Various chemical constituents like alkaloids, coumarins and steroids have been isolated from different parts of tree such as fruits, leaves, wood, root and bark etc. (Sharma *et al.*, 2007). In addition to its use as fresh fruits, a variety of products like jam, squash, candy, slab, beverages, powder, RTS etc. can be prepared from *bael* fruits (Singh and Roy, 1984; Singh *et al.*, 2011). Wide variability in the physico-chemical composition of the fruit has been observed. *Bael* fruits contain 57-74% pulp with yellow to orange color, 1.4-7.0% fibre, 22-24% total soluble solids, 0.36-0.75% acidity and 18-21 mg per 100 g pulp vitamin C. In view of its rich nutraceutical profile, it can supplement the needs of rural people in arid regions where children often suffer from malnutrition. In arid regions of Rajasthan, *bael* can successfully be grown in areas with irrigation facilities; however, it is affected by frost in Bikaner, Jaisalmer and Churu districts. At CAZRI, varieties like Dhara Road, Faizabadi Local, Ayodhya and Lajeet Saimhipuri have been evaluated out of which Dhara Road and Ayodhya were found better than others. At CISH (Central Institute for Sub Tropical Horticulture), Lucknow, two selections i.e. CISH-B1 and CISH-B2 have been made from open pollinated seedling population. Two varieties NB-5 and NB-9 have also been developed at NDUAT (Narendradev

University of Agriculture and Technology), Faizabad. The variety Thar Divya has been released from CIAH-CHES Vejalpur Godhra during 2015. This is an early maturing, drought hardy, vigorous in growth, less spiny, prolific bearer, thin rind, less seed, high pulp with fine fibre and uniform ripening (Singh *et al.*, 2015). Immature fruit drop, fruit cracking and secondary infection after fruit cracking are the major problems encountered in *bael* cultivation in arid areas.

Jhar ber

Jhar ber (*Ziziphus nummularia*) is a most commonly occurring branched thorny shrub species in the Indian desert with a height of 1-2 m. It occupies almost all the habitats including crop lands and grazing lands (Kumar *et al.*, 2005). It is found growing naturally on farm lands and spreads through root suckers and also by seeds. It forms an integral part of rain fed farming system in arid zones of Rajasthan. Under ground suckers of *jhar ber* remain dormant during summer season but they sprout with monsoon rain and complete the life cycle including vegetative growth, flowering and fruiting by November-December. The bushes are headed back at ground level after the kharif cropping season is over. The freshly cut branches along with leaves are collected in small heaps and left for drying in the Sun. After about 6-7 days the leaves fall off naturally with little shaking. The dried leaves are separated from thorny bushes for feeding to livestock while the thorny bushes are also used for fencing purposes. The fruits are mostly round berries with green fruits in early stage which turn yellow or red at maturity and dark brown after drying. The fruits ripen during late November and December and eaten fresh as well as dried. The fruits contain considerable amount of soluble carbohydrates. The dried fruits are grounded (fruits with the stone) and sieved. The sieved powder consumed after meal as mouth freshener is very rich in sugar and ascorbic acid. Leaves called *pala* is rich in protein (12.9-16.9%) and crude fibre are very much palatable to small ruminants and camels. In recent decades its population has been declining due to use of tractors in cultivation which has created threat to its very existence. Hence, there is an urgent need to collect the available biodiversity in *Z. nummularia* and conserve them through *ex-situ* conservation.

Peelu

Peelu (*Salvadora oleoides* Decne) 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. Gupta and Saxena (1968) reported its abundance in Jalore, Barmer, and Jodhpur district in western Rajasthan. Mertia and Gupta (1993) reported its occurrence in duny regions near Indo Pakistan border in the west, covering Murhar-Mehrana, Harro and Jharia areas. Shankar and Kumar (1987) have also reported its abundance in the peripherals of all major runns of Jaisalmer district. The maximum density (120 trees ha⁻¹) of *S. oleoides* was recorded at Shantipura area followed by Bibasar area (112 trees ha⁻¹) in Jalore district of Rajasthan (Khan *et al.*, 2008). Its density varies from 5 to 78 trees ha⁻¹ depending upon the soil types and rainfall. The rainfall range of the species is between 180 to 700 mm annum⁻¹ and it can tolerate maximum temperature up to 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 is a small tree upto 5 m height, gregarious, evergreen with dense round crown and has deep as well as lateral root to utilize the moisture according to availability. The species flowers during January to April (Chundawat, 1990) and ripe fruits called "*peelu*" are available during May-June. The ripe fruits are sweet but immature fruits are highly acid. The fruit contains small seeds which is about 10% of fruit weight. The fruit yield ranges between 30-80 kg per plant from a

full grown up tree (Khan *et al.*, 2008), though, it varies according to prevailing weather at flowering/fruiting and rainfall in preceding year. Great deal of variability in fruit shape, size and color are found due to seed propagation. When dried they taste like currants and are dark brown or red in color. The fresh fruits contain about 70% juice. The method of extraction of juice and preparation of squash and Jam has been standardized (Khan *et al.*, 2004). The seeds are rich in fat (40-50%) which is not edible but have industrial value for preparation of soaps and candle. After extraction of oil the cake is also useful as manure.

Phalsa

Phalsa is an indigenous short duration crop of immense potential but it has not attained much commercial importance due to perishable nature of fruits due to which it can not be transported to distant markets. Asynchronous maturity of fruits enhances harvesting cost being labour intensive. The fruit quality is best in dry climate available in Rajasthan. It is commercially propagated by hard wood cutting during rainy season. Treating the cutting with IBA @ 100 ppm for few seconds before planting helps to enhance rooting in cutting. The presence of mature leaves inhibit axillary bud sprouting. The fruits are borne in clusters in the axil of leaves on current year growth, hence annual pruning is essential. In general under north Indian condition, pruning is done when it sheds off leaves during middle of winter season (Singh, 1979). At Jodhpur, best results were obtained when pruning was done in last week of December at 120 cm height from ground level (Meghwal, 2006).

Prickly pear

Cacti are group of plants native to North and South America and the West Indies. They belong to family Cactaceae having 122 genera with approximately 1600 species which have spines and exhibit stem succulence. Cactus pear (*Opuntia ficus-indica* L.) is the most widely cultivated species and belongs to the sub family Opuntioideae having 250 species. In India, many species of cacti are found growing either as wild plants in arid and semi-arid regions or as ornamental plants in urban homes and gardens. Generally these species are used as live fence to protect agricultural field from human and animal encroachments. With few

exceptions, there has so far been no attempt to cultivate this plant as horticultural or fodder crop in India. In view of specific phenological, physiological and structural adaptation of cacti, it can be considered to cope with the future global climate change. Cactus pear is a crop of multiple uses. It plays an ecological role in soil conservation as well as producing edible fruits and vegetable (nopalitos) for human consumption, forage for livestock and several other value added products having medicinal properties. The edible cactus pear could be considered a new hope for wasteland development (Singh and Felker, 1995). It produces edible fruits and its tender cladodes can be used to prepare vegetable, salad, pickle and as animal fodder. Use of *Opuntia* in natural landscape and as agricultural crop has been adopted in many countries. Most parts of Rajasthan experience extremely high temperature and have scarce water resources, poor and marginal soils and saline irrigation water. In arid lands which are often prone to wind erosion, planting of cactus, can act as biological/physical barrier and may prove to be an easy, cheap and efficient way to prevent top-soil loss, and to facilitate the accumulation of wind-borne deposits. *Opuntia* has been exploited world wide as fruits for table purpose as well as for processing. However, in India it has not been exploited yet. The *Opuntia elatior* is grown naturally in different parts of Rajasthan as live fence. The potential market for species is extensive, so better marketing strategies and post-harvest technology need to be considered also. Due to their management requirements, *Opuntia* spp. demand extensive labor, hence it generates ample opportunities for employment in rural areas.

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 (Felker *et al.*, 1997). All these clones grew well under the semi-arid agroclimate of western Maharashtra and it is reported that some clones also produced fruits (Singh, 2003). 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 National Research

Centre for Arid Horticulture in Bikaner. The last 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 CAZRI Jodhpur during 2010. 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 (Anon., 2013). However, efforts are underway at Jodhpur also to screen the germplasm for high temperature tolerance. While *Opuntia* has the appearance of a drought resistant plant, it is not as tolerant as *Prosopis juliflora*. Henri Le Houerou, a noted authority on cactus, believes that cacti can not be grown in Sahelian Africa where temperature of 45°C and humidity less than 30% prevails. Thus, it remains to be seen if the economically useful cacti will grow and thrive under the harsh conditions (>45°C and rainfall <300 mm annum⁻¹) of the Rajasthan desert (Felker *et al.*, 1997). Shankar and Saxena (1976) reported a technique for raising plantation of cactus in arid areas receiving annual precipitation between 150-250 mm by locating plantation in water channels and valleys. The cladodes were cut at joint and the cut ends were dribbled in the sandy soil upto a quarter of total length of the cladodes at the spacing of 3 m. At the base of each planted cladodes, a crescent shaped ridge slightly raised towards the slope gradient conserved moisture for rapid growth. Erect planting keeping 1/3rd portion of the cladode underground and 2/3rd above ground was found better than flat planting (Singh *et al.*, 2001). Roy *et al.* (2015) studied the effect of cladode age, variety, wax treatment and planting media on propagation of cactus pear at Jodhpur. It was revealed that the bud sprouting began after 15 days of planting in nursery beds and 25 days after planting in case of pots. After four months of planting, more than 80% plants were found rot free while maximum (100%) rot free plants were recorded in six-month-old cladodes of Clone No. 1270 and 1308. No significant differences were observed between wax and non-wax treated cladodes. The planting in pot was significantly better than bed with respect to rot free survival. Number of new cladodes produced varied

significantly in different treatments. The rot free survival was comparatively more in six month old cladodes irrespective of media, cultivar and wax treatment; however, the differences were non-significant. No significant differences were also recorded between wax treated and untreated cladode with respect to rot free survival, number of new leaves formed, root length and number of roots. The highest number of roots (30.33) was recorded in one year old cladode of Clone No. 1270 planted in pots without wax treatments while longest root was recorded in one year old cladodes of the same variety planted in pot with wax treatment.

Common fig

Fig (*Ficus carica* L.) is one of the oldest known fruit trees in the world. The most preferred climate for fig growing is mediterranean regions, with cool winters and hot-dry summers, but it can also be grown in other regions including the tropics and subtropics. Since it is drought tolerant, it can be grown in arid regions of western Rajasthan with little supplementary irrigation. The hot and dry atmosphere improves the quality of fruits. Figs can be eaten fresh or dried and are often used in preparation of jam. Three varieties of fig viz. Black Ischia, Puna and Dinkar were evaluated at CAZRI, Jodhpur. The variety Dinkar was found best with fruit yield of 10-15 kg plant⁻¹ 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 did well at Bangalore (AICRPAZF, 1995). The fig can easily be propagated by cutting planted during February or July months. It can also be propagated by chip or patch budding as well as by wedge grafting in October on vigorous Brown Turkey rootstocks (Anon., 1996). Application of 900 g N + 250 g K to each tree of Poona fig spaced at 5 m x 5 m gave the best results in Maharashtra (AICRPAZF, 1985). The performance trials conducted at CAZRI Jodhpur has indicated that it can successfully be cultivated in arid areas with supplementary irrigation water (Meghwala and Pradeep-Kumar, 2009). In fact the hot and dry weather prevailing during April-May improved fruit quality. No serious disease or pests have been observed at Jodhpur except damage to fruits by birds and squirrels. However, in other parts of India,

fig rust and fig midge has been reported. Sprays of 0.2% chlorothalonil and 0.4% copper oxychloride gave the best control of fig rust (AICRPAZF 1985). The Incidence of fig midge (*Udumbaria nainiensis*) could be considerably reduced by 2 sprays of 0.05% monocrotophos or fenitrothion at 3-week interval starting at 'pea' size fruit stage (AICFIP, 1980).

Persian lime

Persian lime (*Citrus latifolia* Tanaka), also known as Tahiti lime and large fruited lime is bigger than ordinary lime i.e. about 6 cm in diameter, often with slightly nipped ends with thick skin and less aroma. The advantages of the Persian lime in commercial orchard over acid lime are the large fruit size, absence of seeds, cold hardiness, absence of thorns on the bushes, and extended fruit shelf life. They are less acidic than acid limes and don't have the bitterness that lends to the acid lime's unique flavor. To evaluate its performance in arid zone with limited irrigation, air layers were obtained from a private nursery located in Pushkar region of Ajmer district of Rajasthan. The plants were transplanted at 5 x 5 m spacing at CR Farm, CAZRI, Jodhpur during August, 2004. Standard agro-techniques were followed for its cultivation. The evaluation of Persian lime germplasm indicated that it is a fast growing and precocious bearer. The plants attained mean height of 2.28 m and canopy area of 12.06 m² after six years of planting. The fruiting started in third year and reached to maximum of about 20.0 kg per plant in sixth year with mean yield of about 15 kg plant⁻¹ year⁻¹. The fruits borne in clusters of 3-5 fruits were completely seedless with mean fruit weight of 75 g (range 60-90 g). The fruits were rich in juice (56.45%), with 7 °Brix and 5.76% acidity (Anon., 2006). There were two main fruiting season i.e. Jan-February and July-August. However fruit setting was severely hampered by high temperature accompanied by hot winds during April to June. The effect of high temperature was so severe that leaves were burnt and the developing fruit got shrivelled even under the saturated rhizosphere. The effect of desiccating hot winds could be minimized by planting shelter belts in south west direction. Hence, it is suggested that *ambe bahar* should not be taken in Persian lime to avoid the damage to fruits due to adverse weather.

Table 4. Pretreatment of fruits and vegetables for enhancing the quality of dried products (Meghwal, 2008)

Fruits/vegetables	Pre-treatment	Fresh weight (g)	Weight after dehydration (g)	Per cent recovery	Drying ratio
<i>Kair</i>	Blanching for 5 min.	1000	250	25.00	4:1
<i>Gonda</i> (destoned)	Blanching for 5 min.	1850	160	17.70	11.6:1
<i>Ber</i> (destoned)	Sulphuring	1750	356	20.34	4.9:1
<i>Ber</i> (with stone)	Blanching	2350	710	30.12	3.3:1
<i>Peelu</i> (with seeds)	Sulphuring	1000	125	12.50	8:1
<i>Kachra</i>	Sulphuring	2250	350	15.55	6.4:1
<i>Tinda</i>	Blanching	1000	160	16.00	6.25:1
Cowpea pods	Blanching	800	125	15.62	6.4:1
Guar pods	Blanching	900	225	25.00	4:1
<i>Khejri</i> pods	Blanching	1000	190	19.00	6.25:1

Processing and Value Addition in Underutilized Fruits

The underutilized fruits grown in arid regions have been prepared into various processed products by the people utilizing their acquired traditional knowledge like sun drying, pickling etc. However, with the application of modern techniques, the quality of products could be improved considerably. The pretreatment of many fruits and vegetable results in better quality end products (Meghwal, 2008; Table 4). Solar drying and electric tray dehydration of fruits and vegetable help to reduce dust load on the product and retain natural color. Techniques for preparation of different products from underutilized fruits have been standardized (Table 5).

Researchable Issues

- Underutilized fruits of arid zone have remained neglected. Genetic resources of these crops are still available on farmers' field or at

Table 5. Processed products from underutilized fruits of arid zone

Name of fruits	Processed products technique standardized
<i>Bael</i>	Squash, preserve, nectar, powder, slab, etc.
<i>Lasora</i>	Pickle, dried <i>lasora</i>
<i>Karonda</i>	Chutney, Jam, Candy
<i>Peelu</i>	Squash, dried <i>peelu</i> , wines
<i>Kachri</i>	Dried fruits, pickle
<i>Kair</i>	Pickle, dried fruits
Aloe vera	Candy, jelly, pickle, cold cream, crack cream, moisturizer, gel
<i>Tumba</i>	Pickle, candy, preserve

CPRs and need to be included in conservation efforts.

- Research work on underutilized fruit crops should be expanded in order to maximize production and overcome disease and pest problems.
- The germplasm of these crops need to be collected, documented and conserved in field gene banks. Ethnobotanical and nutritional value also needs to be assessed.
- Genetic improvement and development of new varieties.
- Standardization of propagation techniques and timely supply of quality planting materials and development of location specific agrotechniques to exploit these crops commercially.
- Commercialization of processing, packaging and value addition in natural growing areas.

Future Strategies

- Identification of suitable growing areas in respect of each underutilized fruit crop suitable for different soil types of arid region.
- Market linked production and shift in attitude from subsistence farming to commercial orcharding.
- Location specific farming systems involving underutilized crops need to be developed and popularized to ensure its adoption by the farmers of the region.
- Creating awareness among the growers for marketing of produce through cooperative or growers' association so as to fetch better price of the produce for grower's prosperity.

References

- Aberoumand, A. 2011. Survey of some plant foods as sources of antioxidants. *Innovative Romanian Food Biotechnology* 8: 22-25.
- Agarwal, V. and Chouhan, B.M. 1988. A study on composition and hypolipidemic effect on dietary fibre from some plant foods. *Plant Food for Human Nutrition* 38(2): 189-197.
- AICFIP 1980. *Project Report 1976-1980, Cell III, All-India Coordinated Fruit Improvement Project*, Hisar, Technical, Document No I.
- AICFIP 1980. *Project Report 1976-1980, Cell III, All-India Coordinated Fruit Improvement Project*, Hisar, Technical, Document No I.
- AICRPAZF 1995. *Proceedings of Eighth Group Workers Meeting of All-India Co-ordinated Research Project on Arid Zone Fruits*, held during 4-6 January 1997 at Rajasthan Agriculture University, Bikaner, pp. 4
- AICRPAZF 1985. *Proceedings, Third National Workshop on Arid Zone Fruits Research*, held during 5-8 July 1985. Mahatma Phule Agricultural University, Rahuri. All-India Co-ordinated Research Project on Arid Zone Fruits, Hisar, Technical, Document 18.
- Anonymous 1996. *ICAR News* 2(4): 23.
- Anonymous 2006. *Annual Progress Report*, Central Arid Zone Research Institute, Jodhpur.
- Anonymous 2008. *Annual Progress Report*, Central Arid Zone Research Institute, Jodhpur.
- Anonymous 2013. *Annual Progress Report*, Central Arid Zone Research Institute, Jodhpur.
- Arya, S.S., Toky, O.P., Bisht, R.P. and Tomar, R. 1991. *Prosopis cineraria* - A promising multipurpose tree for arid lands. *Agroforestry Today* 3(4): 13-14.
- Chouhan, B.M., Duhan, A. and Bhatt, C.M. 1986. Nutritional value of *kair* (*Capparis decidua*) fruit. *Journal of Food Science and Technology* 23(2): 106-108.
- Chundawat, B.S. 1990. *Arid Fruit Culture*. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi, 189 p.
- Deora, M.S. and Shekhawat, N.S. 1995. Micropropagation of *Capparis decidua* (Forsk) Edgew.: A tree of arid horticulture. *Plant Cell Reports* 15: 278-281.
- Duham, A., Chauhan, B.M. and Punia, D. 1992. Nutritional value of some nonconventional plant foods of India. *Plant Food for Human Nutrition* 42: 193-200.
- Felker, P., Singh, G.B. and Pareek, O.P. 1997. Opportunities for development of cactus (*Opuntia* spp.) in arid and semi-arid Regions. *Annals of Arid Zone* 36(3): 267-278.
- Gupta, I.C., Harsh, L.N., Shankarnarayan, K.A. and Sharma, B.M. 1989. Wealth from wasteland. *Indian Farming* 38(11): 18-19.
- Gupta, R.K. and Saxena, S.K. 1968. Resource survey of *Salvadora oleoides* Decne and *Salvadora persica* L. for non edible oil in western Rajasthan. *Tropical Ecology* 9: 140-152.
- Haseeb, A., Alam, M.M. and Khan, A.M. 1984. Control of plant parasitic nematodes with chopped plant leaves. *Indian Journal of Plant Pathology* 2(2): 180-181.
- Heywood, V.H. 1978. *Flowering Plants of the World*. Oxford University Press, London, 335 p.
- Joshi, G.D., Prabhudesai, V.G. and Salri, M.J. 1986. Physico-chemical characteristics of *karonda* (*Carissa carandas* L.). *Maharashtra Journal of Horticulture* 3: 39-44.
- Kakkar, N.L., Solanki, K.R., Singh, M. and Vyas, S.C. 1991. Micropropagation of *Prosopis cineraria*. *Indian Journal of Experimental Biology* 29: 65-67.
- Karale, A.R., Keskar, B.G., Dhawale, B.C., Kale, P.N. and Choudhari, K.G. 1990. Variability studies in floral morphology and fruit set in seedling population of *karonda*. *Journal of Maharashtra Agriculture University* 15(1): 109-110.
- Khan, H.A., Meghwal, P.R. and Harsh, L.N. 2004. *Salvadora oleoides* Decne: An under utilized economic plant of the desert. *Science Tech Entrepreneur* 12(12): 61-64.
- Khan, H.A., Meghwal, P.R. and Harsh, L.N. 2008. Economic potential of *peelu* (*Salvadora oleoides*)-an important minor forest produce of the desert. In *Processing Technologies for Value Addition of Minor Forest Produce in Tribal Areas: A Step in Rural Development* (Eds. R.K. Gupta and R.T. Patil), pp. 44-47. Central Institute of Post Harvest Engineering and Technology, Ludhiana
- Kumar, S., Farzana, P. and Narain, P. 2005. *Medicinal Plants in the Indian Arid Zone*. Technical Bulletin, CAZRI, Jodhpur, 64 p.
- Mahla, H.R. and Singh, J.P. 2013. Assessment of *in-situ* variability in *kair* germplasm for utilization in genetic improvement through *ex-situ* conservation. *Annals of Arid Zone* 52(2): 109-112.
- Mahla, H.R., Singh, V.S., Singh, D. and Singh, J.P. 2012. *Capparis decidua* (Forsk.) Edgew.: An underutilized multipurpose shrub of hot arid region: Distribution, diversity and utilization. *Genetic Resources and Crop Evolution* 60: 385-394.
- Mallik, S.K., Chaudhury R., Dhariwal, O.P. and Bhandari, D.C. 2010. *Genetic Resources of Tropical Underutilized Fruits in India*. National Bureau of Plant Genetic Resources, New Delhi, pp. 38-46.
- Meghwal, P.R. 2002. Judging culinary maturity of *kair* fruits (*Capparis decidua*). *Current Agriculture* 26(1-2): 75-76.

- Meghwal, P.R. 2006. Effect of time and intensity of pruning on vegetative growth, fruit yield and quality of *phalsa*. *Annals of Arid Zone* 45(1): 59-62.
- Meghwal, P.R. 2007. Propagation studies in *lehsua* (*Cordia myxa*). *Indian Journal of Agricultural Sciences* 77(11): 765-767.
- Meghwal, P.R. 2008. Dehydration of fruits and vegetable from traditional farming systems of arid zone. In *Diversification of Arid Farming System* (Eds. P. Narain, M.P. Singh, Amal Kar, S. Kathju and Praveen-Kumar), pp. 405-407. Arid Zone Research Association of India and Scientific Publishers (India), Jodhpur.
- Meghwal, P.R. and Azam, M.M. 2007. Prospects of horticultural crops of arid zone for processing industries. *International Exhibition and Conference on Processed Food*. Aug. 29-Sept., 2, 2007, Jaipur (Rajasthan).
- Meghwal, P.R. and Harsh, L.N. 2008. Budding in *khejri*: An important technique for conservation and propagation of elite germplasm. *Green Farming* 1(4): 49.
- Meghwal, P.R. and Pradeep-Kumar, 2009. Common fig cultivation in Indian arid zone. *Intensive Agriculture* 48(4): 20-23.
- Meghwal, P.R. and Tewari, J.C. 2002. *Kair* (*Capparis decidua*): A multipurpose woody species for arid region. *Forest, Trees and Livelihood* 12(4): 313-319.
- Meghwal, P.R. and Vashishtha, B.B. 1998. Effect of time of planting and auxin on rooting of cuttings of *kair* (*Capparis decidua* L. Forsk). *Annals of Arid Zone* 37(4): 401-404.
- Meghwal, P.R., Singh, A. and Morwal, B.R. 2014a. Diversity, distribution and horticultural potential of *Cordia myxa* Roxb.: A promising underutilized fruit species of arid and semi-arid regions of India. *Genetic Resources and Crop Evolution*, DOI.10.1007/s10722-014-016-y.
- Meghwal, P.R., Singh, A. and Pradeep-Kumar 2014b. Evaluation of selected *gonda* genotypes (*Cordia myxa* L.) on different rootstocks. *Indian Journal of Horticulture* 71(3): 415-418.
- Meghwal, P.R., Singh, M. and Morwal, B.R. 2012. Collection, evaluation and characterization of *karonda* germplasm in arid zone. Poster presentation in *Symposium on Managing Stress in Drylands under Climate Change Scenario*, December, 1-2, AZRAI and CAZRI, Jodhpur, Abstract, pp. 246.
- Mehra, K.L. and Arora, R.K. 1982. *Plant Genetic Resources of India- Their Diversity and Conservation*. National Bureau of Plant Genetic Resources, New Delhi (NBPGR Science Monogram No. 4).
- Mertia, R.S. and Gupta, I.C. 1993. *Salvadora oleoides* - A promising tree of Thar Desert. In *Afforestation of Arid Lands*. Scientific Publishers, Jodhpur, pp. 111-115.
- Mishra, K.K. 2007. New *karonda* varieties from Pant Nagar. *Indian Horticulture* (Nov-Dec): 9-10
- Mitra, S.K., Majhi, D. Lembisana, Devi, H. and Pathak, P.K. 2011. Potential of underutilized tropical and subtropical fruits of Asia and Oceania. *Acta Horticulturae* 921: 111-115.
- Nagar, B.L., Fagaria, M.S and Pareek, S. 2013. Genetic variation for physico-chemical characteristics in *Lehsua* (*Cordia myxa* L.). *African Journal of Agricultural Research* 8(40): 5047-5050.
- Oudhia, P. 2007. *Cordia myxa* L. In *Medicinal plants/ Plantas medicinales* 1 [CD- Rom & A. (Eds. G.H. Schmelzer and Gurib-Fakim). Prota 11(1) PROTA, Wageningen, Netherlands.
- Pareek, O.P. 2002. Top working wild *khejri* trees. *Indian Horticulture* 4(1): 11-12.
- Pareek, O.P. and Sharma, S. 1993. Underutilized fruits. *Indian Horticulture* 38: 47-56.
- Rai, S. 1987. Chemical examination of edible plants of Rajasthan with special reference to *Capparidaceae*. *Current Agriculture* 11(1-2): 15-23.
- Roy, M.M., Kumar, S., Meghwal, P.R. and Kumar, A. 2015. Prospects of Cactus introduction for improving livelihood in low rainfall regions of India. *Acta Horticulturae* 1067: 239-246.
- Satyanarayana, T., Anjana, A. and Mathews, V.P. 2008. Phytochemical and pharmacological reviews of some Indian *Capparis* species. *Pharmacognosy Reviews Supplements* 2: 36-45.
- Shankar, V. and Kumar, S. 1987. Grazing resources of Jaisalmer District. *Ecology and Developmental Planning with Special Reference to Sewan Grasslands*, CAZRI Publication No. 28, 92 p.
- Shankar, V. and Saxena, S.K. 1976. Spineless cactus as fodder reserve. *Indian Farming* 26(1): 23-24.
- Shankarnarayan, K.A., Harsh, L.N. and Kathju, S. 1987. Agroforestry in arid zones of India. *Agroforestry Systems* 5: 69-88.
- Sharma, P.C., Bhatia, V., Bansal, N. and Sharma, A. 2007. A review on *bael* tree. *Natural Product Radiance* 6(2): 171-178.
- Sharma, V.K. 1997. *Bael*. In *Wasteland Horticulture*, pp. 89. APH publishing Corporation, New Delhi.
- Singh, A.K., Singh, S., Singh, R.S., Bagle, B.G. and Sharma, B.D. 2011. *The Bael- Fruit for Drylands*. Tech. Bull. No.38, CIAH, CHES, Vejalpur, Godhra 46 p.
- Singh, D. and Singh, R.K. 2011. *Kair* (*Capparis decidua*): A potential ethnobotanical weather predictor and livelihood security shrub of the arid zone of Rajasthan and Gujarat. *Indian Journal of Traditional Knowledge* 10(1): 146-155.
- Singh, G.B. 2003. General review of *Opuntias* in India. *Journal of Prickly Pear Association for Cactus Development* 5: 30-39.

- Singh, G.B. and Felker, P. 1995. Edible *Cactus* - New hope for wasteland development. *Wasteland News* 11(2): 58-61.
- Singh, G.B., Tiwari, R.K., Bajpai, C.K. and Solanki, K.R. 2001. Studies on exploitation of edible *cactus* in red soils of Bundelkhand. *Indian Journal of Soil Conservation* 29(2): 184-186.
- Singh, M., Jindal, S.K. and Sivdasan, R. 2005. *Capparis decidua*: A multipurpose shrub. In *Shrubs of Indian Arid Zone* (Eds. P. Narain, M. Singh, M.S. Khan and S. Kumar), pp. 97-104. Central Arid Zone Research Institute, Jodhpur
- Singh, M.P. 2007. The phenomenon of mortality in *Prosopis cineraria* trees in some arid districts of Rajasthan. In *Mortality in Agro Forestry Trees* (Eds. D.P.S. Nanda and J.C. Kaushik), pp. 67-76. CCS HAU, Hissar.
- Singh, R. 1979. *Fruits*. National Book Trust, New Delhi.
- Singh, R.N. and Roy, S.K. 1984. *The Bael*. Indian Council of Agricultural Research, New Delhi, 25 p.
- Singh, S., Singh, A.K., Apparao, V.V. and Bhargava, R. 2013. Thar Kamal: A new *karonda* variety. *Indian Horticulture* 58(4): 9-10.
- Singh, S., Singh, A.K., Meghwala, P.R., Singh, A. and Swamy, G.S.K. 2014. *Karonda*. In *Tropical and Sub Tropical Fruit Crops: Crop Improvement and Varietal Wealth*, Part I (Ed. S.N. Ghosh), pp. 392-405. Jaya Publishing House, New Delhi.
- Singh, S., Singh, A.K., Singh, R.S. and Sharma, S.K. 2015. Thar Divya: An early maturing variety of *bael* for drylands. *Indian Horticulture* 60(6): 11-13.
- Tyagi, P. and Kothari, S.L. 1997. Micropropagation of *Capparis decidua* through *in vitro* shoot proliferation on nodal explant of mature trees and seedling explants. *Journal of Biochemistry and Biotechnology* 66: 19-23.
- Vashishtha, B.B. 1987. Vegetative propagation of *Capparis decidua*. *Annals of Arid Zone* 26 (1&2): 123-124.
- Vishalnath, Pareek, O.P., Saroj, P.L. and Sharma, B.D. 2000. Biodiversity of *khejri* in arid regions of Rajasthan: Screening of *khejri* for culinary value. *Indian Journal of Soil Conservation* 28(1): 43-47.
- Vyas, G.K., Sharma, R., Kumar, V., Sharma, T.B. and Khandelwal, V. 2009. Diversity analysis of *Capparis decidua* (Forsk.) Edgew using biochemical and molecular parameters. *Genetic Resources and Crop Evolution* 56: 905-911.