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Conservation and management of plant genetic resources of arid fruits : A review

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Abstract

Arid climate is characterized by harsh environmental conditions such as low rainfall, high evapo-transpiration and high temperature. The arid zone soils are very poor in fertility, organic matter and water holding capacity. The soils of the north-western arid region described as 'desert soils' and order of Aridisols are light in texture. The ground water resource is not only limited but is also of saline quality. The average annual rainfall is very low and varies from 100 mm in north- western sector of Jaisalmer to 450 mm in the eastern boundary or arid zone of Rajasthan. The rich genetic diversity is available in arid fruit crops such as ber (*Ziziphus mauritiana);* boradi (*Ziziphus rotundifolia*), Lasoda (*Cordi*a *myxa*), Ker (*Capparis decidua*), Phalsa (*Grewia subinaequalis*), Pomegranate (*Punica granatum*), Date palm (*Phoenix dactylifera*),Bael (*Aegle marmelos*), Pilu (*Salvadora spp.),* Karonda (*Carissa carandus*), Fig (*Ficus carica*), Wood apple (*Feronia limonia*), Mulberry (*Morus* spp.), Manila tamarind (*Pithocelobium dulce*), etc. and it should be conserved for crop improvement programme. Due to hardy plant types, these fruit plants can thrive well under drought situations, which is common feature in arid region. The fruit crops which have the potential for commercial exploitation are yet to be exploited to their potential for providing food and livelihood security in semi arid and arid parts of the country. These fruit plant species produce edible nutritious fruits and other products of economic importance. In this paper, the genetic variability, conservation and utilization in arid fruits have been discussed for genetic improvement and sustainable production in arid region.

Kew words: *Arid fruits, germplasm conservation, genetic diversity, arid region,*

Introduction

A wide range of genetic variability is available in arid fruit crops which are mainly grown in arid and semi arid parts of the country. However, this vast genetic pool has so far largely remained underutilized. Conservation of plant genetic resources is essential for future crop improvement programmes (More and Singh, 2008). This genetic variability can be effectively utilized for the development of desired varieties in fruit crops as limited work has been done on arid fruit crops, which are perennial in nature. The common objectives in crop improvement of arid zone fruits till now have been to improve the quality attributes and appearance of fruits in addition to fruit yield. These goals were achieved mostly by exploiting the naturally occurring intra-species variability in fruit species. Most of the varieties grown, presently, are seedlings or clonal selections. The other important objectives in breeding of arid fruit crops includes the development of varieties / rootstocks, which perform well even under extremes of temperature regimes and can withstand water stress or have low water requirement, besides tolerance for other abiotic and biotic stresses. Frost is common features in hot arid region. To date, there are no varieties in arid zone fruits against frost/low temperature tolerance. Traits like dwarf canopy in order to increase orchard plant density, selecting self-fertile genotypes to maintain a higher consistent yield over time and selecting genotypes with higher nutritional value of the fruits also need to be taken into account in breeding depending on the fruit crop, which is to be dealt with. India is home of variety of minor fruit commonly found in semi arid and arid regions which includes ber, aonla, fig,lasoda ,karonda phalsa, ker and Khejri (Dhillon and Saxena,2005).

Improvement of fruit crops is difficult owing to long gestation period, high heterozygosity, scanty information on inheritance pattern, often cross pollination, excessive fruit drop, polyploidy and less number of seeds per fruit restricting the availability of hybrid seedlings for evaluation. These characteristics make breeding techniques difficult, expensive and time consuming. Even though, planned hybridization and clonal selection have been attempted in a number of fruit crops and these efforts have resulted in the development of promising varieties in grape, guava, sapota etc. This explains why some fruit crops have been improved almost exclusively with clonal selection, using variability from spontaneous mutations or selecting plants derived from natural hybridization. There is vast potential in crop improvement in underexploited fruit crops of arid region. Recently molecular and biotechnological approaches such as somaclonal variation, gene transformation or protoplast technology provide the scope for making significant changes to varieties, but less progress has been made in the

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arid zone fruit crops (Singh *et. al.,* 2012).However, systematic and dedicated efforts are still required for the development of ideal varieties through modern tools in arid fruit crops (Shukla *et. al.,* 2011).

In this review paper, genetic variability, varietal status, breeding approaches and progress made will be dealt, while taking into account work done at different places in our country on arid fruit crops such as ber, pomegranate, bael, aonla, custard apple, date palm, phalsa, lasoda, wood apple, tamarind and fig.

Table 1. Status of Germplasm of Arid fruits at National Active Germplasm Site (NAGS).

CIAH, Bikaner			**CHES, Godhra**		
Name	**Scientific name**	**No.**	**Name**	**Scientific name**	No.
Ber	*Ziziphus mauritiana*	318	Ber	*Ziziphus mauritiana*	55
Bordi	*Z. rotundifolia*	22	Custard apple	Annona squamosa	09
Pomegranate	*Punica granatum*	150	Pomegranate	*Punica granatum*	45
Aonla	*Emblica officinalis*	10	Aonla	*Emblica officinalis*	14
Date palm	*Phoenix dactylifera*	60	Sapota	*Achras zapota*	07
Bael	*Aegle marmelos*	17	Bael	*Aegle marmelos*	40
Jamun	*Syzigium cuminii*	02	Jamun	*Syzigium cuminii*	50
Cactus pear	*Opuntia ficus indica*	20	Tamarind	*Tamarindicus indica*	25
Phalsa	*Grewia subinaequalis*	06	Phalsa	*Grewia subinaequalis*	02
Fig	*Ficus carica*	03	Fig	*Ficus indica*	05
Mulberry	*Morus spp.*	15	Mango	*Mangifera indica*	52
Marula nut	*Sclerocarya birrea*	01	Wood apple	*Feronia limonia*	10
Sweet orange	*Citrus sinensis*	03	Karonda	*Carissa carandus*	40
Karonda	*Carissa carandus*	08	Mahua	*Madhuca latifolia*	50
Lasora	*Cordia myxa*	65	Chironji	*Buchanania lanzen*	30
Pilu	*Salvadora spp.*	02	Khirni	*Manilkara hexandra*	30
Ker	*Capparis decidua*	06			
Manila tamarind	*Pithocelobium dulce*)	03			

Conservation and Management of Genetic Resources of arid fruits:

There are two principal methods of germplasm conservation, which are referred as '*in situ*' and '*ex situ*' conservation approach. *In situ* refers to maintaining plants in their original habitat for instance at farmers' fields (also known as on-farm conservation), while *ex situ* conservation imply maintaining plants outside their original habitats under facilities like genebanks, field gene banks/ NAGS or botanical gardens. Experience shows that diversity is only secure when diverse conservation strategies are employed. *Ex situ* and *in situ* approaches are not mutually exclusive; no single method of conservation is optimal for all situations, and no single method can succeed alone. Different conservation systems can complement each other and provide insurance against the shortcomings of any one method. Germplasm of arid fruits have been collected and conserved in field gene banks at AICRP on AZF centres located in different parts of country (Dhandar and Singh, 2004). However, in this paper, emphasis has been made primarily on *ex situ* approaches as documentation is available on the status of *in situ* germplasm conservation in arid fruit crops.

Ber (*Ziziphus mauritiana Lamk.*)

The genetic diversity exits in ber growing areas of the country and it should be exploited for different traits. Maximum variability in ber is available in dry parts of country as well as desert. Several ber germplasm including species, cultivars and other types have also been collected at different Research stations in the country and are being maintained in the field gene banks. Among various field gene bank centres, CIAH, Bikaner; NBPGR, Jodhpur; MPKV, Rahuri; CCS HAU, Hisar; CAZRI, Jodhpur, Regional Station, PAU, Bahadurgarh, SDAU, S.K. Nagar are important centres . At CIAH, Bikaner highest collections (318) have been made in the National Field Repository. A large number of cultivars (> 150) are in cultivation in India. In India, a number of varieties have been developed and released through selection methods**.** Most of the common cultivars are the result of selection made by local people in different regions of the country. The promising cultivar under commercial cultivations are Gola, Seb, Banarsi Karaka, Banarsi Pebandi, Kaithali, ZG-1, Sanaur-1, 2, 3, 4, Katha, Umran, Mundia, Chonchal, Illaichi, Rashmi, etc. (Shukla *et al*, 2011). B.S.75-1 variety of ber has been developed from CCS HAU, RRS, Bawal

which is resistant against fruit fly and powdery mildew. Hybridization work is going on in ber at HAU, RRS, Bawal and highest fruit yield was obtained in Hybrid-1 (64.7 kg/tree) and incidence of powdery mildew was negligible followed by Hybrid-10 (63.7 kg per tree) (Anon., 2011).

Narendra Ber Selection-1 has been released from NDUA&T, Faizabad and it is performing well under climatic conditions in Eastern UP (Anon, 2011). The new promising ber varieties such as Thar Sevika and Thar Bhubharaj developed by CIAH, Bikaner for cultivation in arid conditions has been released (Shukla *et al.*, 2004).

Thar Sevika (CIAH Hybrid -1): It has been developed by the hybridization from a cross Seb x Katha. Thar Sevika is an early maturing variety. The fruits are juicy, sweet with a TSS content of 22-24%. Fruits after consumption do not cause throat soaring, which is common in other cultivars. Average fruit yield of five year old tree is 30-32 kg/tree. The hybrid is also suitable for staggered picking which can be done up to third week of January.

Thar Bhubharaj: A selection from local material of Bhusavar area of Bharatpur district of Rajasthan, CIAH-Selection-1 is an early maturing cultivar having an average yield potential of five year old tree is 30-35 kg/tree. It is free from fruit rot. The fruits are ready for harvesting during last week of December-first week of January. The fruits are very juicy, sweet with a TSS content of 22-23%.

Goma Kirti: It is a clonal selection from cultivar Umran and developed at CHES, Godhra, Gujarat. It is a clonal selection from cultivar Umran done at CHES, Godhra. It is high yielding, early maturing variety, which fetches good price in the market. Fruit yield potential at 5 year age is 35.60 kg per tree. Fruit size is 3.97 x 3.05 cm. TSS is 30.7° brix. It has superior keeping quality. It is resistant to various diseases and pests by virtue of its earliness (More *et al*, 2008).

Pomegranate (*Punica granatum*)

Pomegranate (*Punica granatum*) belongs to family Punicacae with 2n = 16 chromosomes. The fruit has wide consumer's preference for its attractiveness, juicy, sweet:-acidic ratio and refreshing arils. There is also a growing demand for good quality fruits both for fresh use and processing into juice, syrup and wine. Pomegranate production has attracted several growers in India, but the genetic improvement of this fruit crop has not received much attention.

There are several varieties of pomegranate both adapted to tropical and sub-temperate climate. Some are evergreen while others are deciduous. In India, until recently Ganesh pomegranate variety was by far the most popular one. Improvement in pomegranate has been made through selection and a number of selections have been developed (Choudhari and Shirsath, 1976). This is a seedling selection from a hard seeded 'Alandi'. It produces large size (400-450 g), fruits with sweet (16-17^{0}Brix) arils containing soft seeds. But the arils are pink or light pink in colour. Phule Arakta and Bhagawa variety has been released from MPKV, Rahuri, Maharashtra during 2001. These varieties are suitable for export purpose. Three varieties viz., 'Ruby', 'Phule Arakta', 'Mridula' with red aril colour were developed using 'Ganesh' as base. Phule Arakta is a segreegant of Ganesh x Gul-e-Shah Red having deep blood red soft sweet arils of average fruit weight 250-350g. Bhagava is also segregate of Ganesh x Gule-e-Shah Red having attractive cherry colour soft, sweet arils and with better keeping quality of fruits. The average fruit weight is of 350 to 400g. All these varieties derive genes for red aril colour from Russian temperate varieties. 'Ruby' is a multiple hybrid resembling more of 'Ganesh', but for the red aril colour, while 'Arakta' is A F_2 selection for dark red arils. Among the 16 Bhagava types collected Sel. No.-4 registered lowest maturity period (177days) higher numbers of fruit per plant (52), maximum juice percentage (56.6%) and maximum fruit weight (298.7g).

Recently, another variety under various names-'Bhagava', 'Ashtagndha', 'Mastani', 'Keshar' Sinduri has gained popularity among the growers for its external and internal attractive colour with good shelf life because of thick skin, although it has slightly hard seeds and slow to mature within about 5-6 months (Anon, 2008). There are several other seedling selections which are grown on a limited scale across the country like 'Yercaud', Co-1 (Tamil Nadu), 'Dholka' (Gujarat), 'Jalore Seedless', 'Jodhpur Red' (Rajasthan), Muscat (Maharashtra) and 'Panji' (Goa). In Himachal Pradesh, a sour pomegranate-'Daru', comes abundantly in wild. A rich genetic diversity has been observed in foot hills in Himachal Pradesh (Singh and Singh, 2006). The sour type pomegranate is utilized for anardana purpose. It has potential to exploit for further improvement. Remarkable variability was observed among clones for fruit length, weight, number of arils per fruits and dry weight. This is used mostly in the preparation of *anardana*, an acidulant product used in the culinary preparation. 'Amlidana' is a F_1 hybrid variety suitable for *anardana* production was developed at IIHR, Bangalore. Amlidana is an F_1 hybrid (Ganesh x Nana). It grows well under tropical climate .with quality fruit attributes Amlidana is superior to sour variety Daru , whose trees come up naturally in temperate region of north India . Its fruits provide more acidic (16.18%) anardana and higher fruit yield/tree. In addition, short-statured trees are suitable for high-density planting, giving increase fruit yield/unit area (Jalikop *et. al*., 2002). Under evaluation of germplasm, Amlidana was found suitable for hot arid region for anardana purpose (Singh *et al*, 2011a). However, collections made from H.P. were also found promising for utilization.

Pomegranate is often-cross-pollinated crop and is genetically heterozygous, thus a large variation for several plant and fruit traits is generated in nature as well as upon crossing. Hence, breeding of new varieties may be achieved by seedling selection, hybridization followed by selection or through mutation. However, mutation breeding has some limitations, as it is only a 'hit and miss' method and needs raising of large population to get a

desirable mutant. Development of pomegranate varieties through hybridization mainly involves crossing of selected genotypes, raising of hybrid population, evaluation of hybrids for desirable traits and identification of superior types, which can either be released for general cultivation after elaborate testing could be used in subsequent breeding programme.

When the breeding objective is for disease resistance, like bacterial blight, the progeny should be screened both in the nursery and in field and the resistant types are selected which often require further improvement for fruit traits. Currently two sources of resistance for blight viz., *'Daru'*- a wild sour pomegranate, and *'Nana'* - an ornamental *bonsai* like type have been recognized. If such non-cultivated types are involved in the breeding work, in order to eliminate several undesirable traits, one has to go for repeated backcrosses by making selection in each generation. Once the superior selections are made, they have to be multiplied by air layering and tested against appropriate ruling varieties in a replicated trail before identifying for release. Multi-location evaluation is preferred. Screening of 52 hybrids is in progress. All genotypes were produced sweet arils and low acidic fruits.

Goma Khatta: This variety is developed at CHES, Godhra, Gujarat for Anardana purpose. The yield potential is 6.59 kg/plant and anardana yield is 1.18 kg/plant. Seeds hardiness is medium. Fruit having 46.7% of Juice and TSS is 14.5^{0}Brix. Acidity is 7.3% (More *et al*, 2008).

Pomegranate breeding is slightly easier as compared to breeding of several other fruits as it bears large flowers making hybridization convenient, and produces fruits having abundant seeds, which generally germinate well, and the crop has relatively shorter juvenile phase.

Bael (*Aegle marmelos* Correa.)

Bael plant is found growing naturally in Uttar Pradesh, Bihar, Jharkhand, Madhya Pradesh, Orissa, West Bengal and Chhattisgarh with large genetic variability, which should be exploited. In Uttar Pradesh, Deoria, Basti, Gorakhpur, Gonda, Faizabad, Sultanpur, Jaunpur, Pratapgarh, Mirzapur, Allahabad, Lucknow, Etawah, Agra, etc. are the districts where large number of promising genotypes are either growing naturally or planted near the houses. There is a fast genetic erosion in wild bael genotypes, therefore, its conservation has become necessary (Srivastava *et al*., 1998). Rai *et al.* (1991) reported vivid account of bael genetic diversity available in India. The variability in bael germplasm was observed in identified types at different locations (Rai *et al*., 1991). Apart from the tree morphological characters, wide variability exists in fruit size and shape, bearing habit, flesh colour, texture, fibre content, sugar content, mucilage content, etc in different parts of country(Singh *et al*,2009; Vishalnath *et al*,2003). In Jaunpur area of UP, very old naturally growing bael plants are available. Some types have more number of seeds, gum locules and thick pericarp (Misra *et al*., 2000). However, some selections have been made at NDUA&T, Faizabad and GBPUA&T , Pantnagar and CISH, Lucknow, which are gaining popularity for commercial cultivation. At Central Institute for Arid Horticulture, Bikaner also collection of bael germplasm has been done, which are under evaluation. Besides this, some germplasm were also collected from nursery/farmers' field and maintained in the field repository at CAZRI, Jodhpur; CISH, Lucknow, CCS HAU, RRS , Bawal; NDUAT, Faizabad, GBPUAT, Pant nagar and TNAU, Aruppokottai for conservation and evaluation. Lal (2002) evaluated 12 genotypes collected from Jaipur (Rajasthan) and found that 8 genotypes produce fruits of excellent quality under semi-arid conditions. In Chomu area of Jaipur, fruit sample from seedling plants were collected during 2009. Variation was observed in fruiting, size, quality of fruits and two genotypes were identified. Fruit cracking was also observed in bael trees grown in Sikar district.

It belongs to family Rutaceae having chromosomes number x=9 and 2n=36. There is a wide range of genetic diversity in existing population and ample scope for selection of promising genotypes. Low seeded, less mucilage and medium size fruit is needed with high nutritive and medicinal value. In view of limitations of conventional methods of breeding, biotechnological approaches should be tried for improvement in bael. Recently bael NB-16 and NB-17 from NDUA&T, Faizabad and CISH B-1 and CISH B-2 from CISH, Lucknow has been released for commercial production. Pant Aparna, Pant Sujata, Pant Urvashi and Pant Shivani have been developed from G.B. Pant University of Ag. & Tech. Pantnagar (Singh *et. al.,* 2011) and are suitable for commercial cultivation in different parts of country.

Goma Yashi: It is developed through selection and released from CHES, CIAH, Godhra Gujarat. It produces very good quality fruit with weight of 1.0 to 1.25 kg/ fruit. Fruit are ovate in shape, greenish yellow. Plants are of drooping type and suitable for high density planting. It is early maturing variety. Flesh colour is straw colour.

Fruit shell weight is 180. Number of locules is cross section/ fruit is 17. It is suitable for dry land condition and fruit cracking is also less. The fruit yield in a six years old plant is 40-50kg.

Aonla (*Emblica officinalis* Gartn.*)*

Aonla is medicinal fruit tree and generally growing in the forests and also cultivated in systemic manner. A number of aonla variety series like NA-6, NA-7,NA-9, NA-10 have been developed from NDUA&T, Faizabad;,Annad Aonla-1,Aonla-2, from AAU, Anand, and CISH, Lucknow. Laxmi-52 aonla is a selection and recently released from CISH, Lucknow. The genetic diversity of wild grown aonla is found in forests throughout the country which are still unexploited for their commercial utilization and conservation. It is a salinity and drought tolerant plant but susceptible to low temperature in arid region. Fruit is used for making several ayurvedic medicines and for making value added products such as squash, juice, candy, preserve, sweets, mouth freshener,etc.. Very little efforts have been made to collect vast variability for valuable traits like bearing potential,

nutritional and medicinal value, insects & disease resistance, frost tolerance, etc. Almost all varieties are developed through selection methods in Aonla (Mehta and Singh, 2003). Recently, a selection from plus tree, Goma Aishwariya an early, drought tolerant variety has been released from CHES, Godhra. The average yield potential is 102.9 kg/tree. It has low fibre content and is suitable for processing and export (More *et al*, 2008). Aonla BSR-1 small sized fruit, good bearer, reddish colour fruit, has been released from TNAU, Coimbatore. In aonla, the major problem is of frost/low temperature and there are no varieties available to tackle this problem especially in hot arid region. Development of suitable genotypes of frost resistant is required.

Annona fruits *(Annona chenimola*)

Annona is one of the 40 genera of Annonacae family. It has 120 species, 5 of them have pomological significance. Among the edible *Annonas*, cherimoya (*Annona cherimola*.), sugar apple (*A. squamosa*) and the hybrid between the two, atemoya, are most popular. The other less important edible *Annona* species are *A. reticulata* L. (Bullock's Heart), *A. diversifolia* (Ilama) and *A. muricata* (sour *spp*). The edible *Annonas* species differ for fruit traits and are amenable for genetic manipulation, as they cross with each other easily. Each species can benefit from the other edible *Annonas* for one or the other specific fruit and/or plant traits and hybridizing them should generate useful recombinants as illustrated by the popular *atemoya*.

Among the annonaceous fruits, sugar apple, locally called *sitaphal* or *sharifa* is by far the most relished and widely consumed fruit of India. Most of the *Annona* varieties in cultivation were often developed by clonal or seedling selection by mainly exploiting the intra species variability. Sugar apple plants come in wild abundantly in the vast arid tracts of the country. There are few varieties like Balanagar, Red Sitaphal, Local Sitaphal, British Guinea, Mammoth and Washington. Presence of several big seeds and poor shelf life are the major constraints limiting cultivation of *sitaphal* fruit on a commercial scale.

Inter-specific hybridization:

Evolving *Annona* hybrids is primarily same as described for pomegranate, only care necessary is that the hybrid seeds have to be stratified by keeping under running water for about 48 hours for better seed germination. *Annona* breeding was initiated at Indian Institute of Horticultural Research, Bangalore, several intra- and inter-specific hybrids were produced and evaluated, which resulted in isolation of variety 'Arka Sahan' from the cross atemoya (cv. Island Gem) x Sugar Apple (cv. Mammoth). This exemplifies the use of allied species in breeding of arid fruits, if the traits of interest are not detected in the same species. Hybridization work is also being done in Custard apple at MPKV, Rahuri and Hybrid No. -6, Hybrid No.-13 and Hybrid No.-22 have been found promising. Hybrid No.- 13 has bigger fruit size and less seed percentage (7.02%) and TSS 26% with higher yield (12.3kg/plant) than other hybrids.

Fruit set in *Annonas*

'Arka Sahan' has remarkable sweetness (>32^{o} B TSS; 22.8% total sugars), scanty small seeds (9/100 g fruit weight) and slow ripening (6-7 days). The pulp is snow-white (76%), mealy and juicy with a mild pleasant aroma. As in other *Annonas*, in this hybrid also few flowers of (about 1-2%) develop into fruits owing to male and female structures maturing at different time, besides limited insect and wind pollination. To supplement this, simple artificial hand pollination was worked out by testing different pollen source. Hence, even after a superior genotype is isolated, sometimes it may require further improvement in order to realize the full potentiality of the genotype.

APK (Ca)-1 is a custard apple variety developed through selection and released by RRS, T..N.A.U., Aruppukottai for rainfed conditions. It has good bearing habit. The average fruit weight is 182.2g, pulp weight 11.13g per fruit and TSS 27.9^{o} brix.

Date palm (*Phoenix dactylifera* L.)

A rich genetic diversity is available in costal belt of Kachchh region, Gujarat in India which should be exploited (Singh *et al*., 2009). In other parts of country, seedlings are growing in meagre population. At CIAH, Bikaner, 60 genotypes/ cultivars have been conserved in National field gene bank collected from different available sources as well as introduced from abroad. Further, SDAU, DRS, Mundra, (Gujarat); CAZRI, Jodhpur, SKRAU, Bikaner, PAU, RFRS, Abohar, (Punjab); Central State Farm, Jetsar, Sri Ganganagar, has also maintained and evaluated the date palm germplasm. There is no hybrid reported in date palm so far. Further, no breeding work has so far been taken up on date palm in India except evaluation of cultivars/genotypes against rain damage and selection of some promising female seedlings from the Kachchh region of Gujarat. Most of the cultivars of date palm have introduced from different countries from time to time e.g. Halawy, Barhee, Medjool, Khalas, Sayar, Zahidi (USA), Khadrawy (Iraq), Barshi , Khuneizi, Nagal, Khashab (Oman), Hatemi, Tayar, Ruziz (Saudi Arabia), Amri, Sakloti, Agloni, , Chipchap and Braim (Iraq) during 1998. Sewi and Amhat (Egypt) during the year 2009. Both cultivars have established well under field conditions.

All the commercial date cultivars have developed through selection of chance seedlings based on local needs. From the rich genetic diversity of nearly 1.66 million palms developed from seeds in the coastal belt of Kachchh region of Gujarat, 20 promising palms have been selected, most of which yield non-astringent fruits at doka stage (Muralidharan *et al.*, 2008). One of them bears coconut shape fruit. These selections flower twice in a year. An early ripening date seedling has been identified at Abohar.

At Abohar, Zahidi cultivar has been found to be resistant to rain damage; Barhee is more tolerant than Shamran. It was also found that Medjool is resistant to rain damage, as it missed rains during fruit ripening, which is a late maturing cultivar. A large number of varieties and some promising selections (Sel. - 9, Sel.-13, Yaqubi, Kotho, Trofo, Gulchati, Bhugoso, Madhepura, Khedoi-7, Sopari,

Saidy,) have been made in our country from natural populations existing in Kachchh region. Some selections have also been made by the farmers of the region (Muralidharan *et al.*,2008). Further, these yellow and red berry colour types are suitable for making different processed products (Singh *et al.,* 2011). An elite type of green colour, sweet berry at doka stage has been identified from seedlings population in Kachchh region of Gujarat.

Fig (*Ficus carica* L.)

The edible fig (*Ficus carica* L.) is well known since prehistoric times. Currently several tropical countries are growing fig as a commercial fruit crop and it has emerged as an important fruit in the world trade. Fresh fruits have a luscious taste and are highly nutritious but fruits are mostly sold in the dried form as figs are easily handled and keep well in dried state. Fig is grown in more than 3000 ha area in our country.

Poona Fig is the most popular cultivar in our country. The varieties Bangalore, Bellary, Coimbatore, Daulatabad, Dindigul, Ganjam, Hindupur, Lucknow and Saharanapur have clearly acquired the names from the locations in which they are grown. Since, these varieties resemble cv. Poona Fig in plant and fruit morphology, they are possibly clones or ecotypes of cv. Poona Fig and hardly warrant varietal status. Dinkar, an improvement over cv. Daulatabad for yield and quality is a recently identified variety, both of which resemble Poona Fig variety in fruit characteristics. The other varieties Black Ischia, Shahi, and Maisram are yet to achieve prominence. As many as 700 varieties of fig are known in the world and there is good scope to introduce, evaluate and popularise the exotic fig varieties in our country. Recently some promising types have identified.

In India hybridization programmes in fig have yet not been initiated. California is a major producer of fig in the world and strategic-breeding programmes are going on since several decades at University of California. In 1986, Indian Institute of Horticultural Research introduced 20 promising hybrids /varieties from California. When these varieties were raised from the rooted cuttings in the field they put-forth very little growth and produced very poor crop. However, the fruit quality was excellent. Therefore, Brown Turkey, a vigorous growing entry in the germplasm was identified for chip budding the exotic figs on it. The rootstock was successful in imparting vigour and precocity to otherwise slow growing varieties.

Three exotic varieties viz., Deanna, Conadria and Excel were found promising. All the exotic types are early, and like Indian edible figs, fruit develop syconia parthenocarpically *i.e.*, without the interference of fig wasp, which assists pollination in several edible and non-edible types. The eye or ostiole of fruits of cv. Poona Fig is loose which facilitates easy access to pulp for insects and fungi. Thus the ripe fruits spoil quickly and the fruits split open at the ostiole. However, the tight eye of Conadria and Excel protect the fruit from spoilage and splitting (Anon, 2011).

Deanna produces large sized fruits while fruit size of cvs. Conadria and Excel is comparable with Poona. Fruit shape is pyriform in all the varieties, except Excel, which has ovoid fruits. No clear difference is noticed between Poona Fig and exotic types for total soluble solids. Fruits of cvs. Deanna and Excel, which are suitable for drying, retain their colours even after processing. The new introductions hold great promise for expanding area under fig in India. They also offer a good opportunity to farmers for exploiting the marginal land in arid and semi-arid regions where this fruit can be grown successfully. Thus introduction of appropriate promising varieties, testing and popularization (if found suitable) can be easy, fast and straightforward approach in expanding area under cultivation of given arid fruit crops.

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. Bunch of light yellow colour, hermaphrodite fragrant flowers born 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 (Pundhir, 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. According to Pundhir (1987), fruit setting was about 33.0 % and application of GA at 100 ppm produced the highest fruit set (59.96 %). Flowers are pedicillate, complete, perfect and actinomorphic. Individual florets are nearly 5 mm in diameter. At places these are somewhat hairy and white. The calyx part of an independent flower is about 8 mm long and glabrous, but not pubescent. It splits irregularly at the opening of its bud into flower. The filaments are hairy. Bunch of light yellow coloured hermaphrodite fragrant flowers are borne axillary on current season's growth. Fruits are formed soon after flowering and ripen during MayJuly, while the immature green fruits are available during April-June. Fruit is drupe, 13 cm long, yellowish brown and pink at ripening. The pulp is sweet, viscid, and transparent surrounding the stone (Yadav and Goel, 2006). 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).

Great variation exist in natural population with respect to morphological characters particularly plant height, spread, leaf size, fruit size; fruiting behaviour; quality parameters like fruit colour, pulp content, pickling quality, seed and pulp ratio etc. Even, there is a small fruited types of lasoda locally called as gundi of which fruit is very small size (about 1 cm), orange to light pink in colour at maturity but very much liked by the rural people of western Rajasthan and Gujarat.

The proper efforts have not been done to conserve

genetic diversity of lasoda trees. However, in the recent past some efforts have been made by NBPGR Regional Station, Jodhpur and Central Institute for Arid Horticulture, Bikaner to identify some big fruited types with high productivity. At CCS HAU., Hisar, different genotype was evaluated by Saini *et al.* (2002) and they have reported variability in plant height and spread. Kaushik and Dwivedi (2004) reported wide range of biodiversity in morphological and quality characters from 45 collection of *lasoda* from Haryana.

There is no named or improved cultivar in lasoda. In general, two types of plants viz., large fruited and small-fruited are found growing and are sold by nurserymen. Large fruited cultivars have an average fruit weight of 8.55 g, whereas small-fruited cultivars have fruit weight of 3.0 g. In case of large fruited cultivars, fruit have comparatively more pulp thickness and therefore are suitable for consumption. A large fruited types in Gujarat also recognized as 'Paras Gonda', is a general term for any fruit variety with big size fruits. Similarly in Rajasthan 'Puskar Local' is of big size with good fruit shape. At CIAH, Bikaner under *ex-situ* conservation, 65 types of lasoda have been collected and planted under field conditions to identify promising types. One promising type of lasoda has been identified**.** CIAH Selection 1 is performing well under irrigated hot arid ecosystem with respect to fruit size, pulp content and productivity. The average annual production of tender fruit is more than 100 kg tree (Vishalnath *et al.,* 2008). However, plants are susceptible to frost/very low temperature during winter season. It is most suitable tree for wind break and shelterbelt because its growth is very fast and dense foliage. No systematic work has been conducted on its water and nutrients requirement. Attack of diseases and insects is less on lasoda plants in arid region. The average yield of tender fruit is about 50 - 60 kg/ plant. The potential of lasoda tree in arid region should be exploited at commercial scale.

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. 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 jaggary for improvement of the quality. Pruned phalsa canes/shoots can be utilized for making baskets to transport fruit and vegetables to distant market.

There is no remarkable variability found in case of phalsa except erect and bushy type plant habit. It is mainly grown on boundary of farm and orchards. The genotypes large fruit size with less seeds and high pulp content should be identified and utilized. The fruit is highly perishable and used as fresh as well for processing purposes. There are no known varieties except local types. Its improvement requires varieties with long storability and keeping quality. It is mainly planted in orchards as filler crop and as hedge plants on the boundary. It can be planted at 2-3m distance. Fast growth of plants and regular pruning has good potential for its cultivation. It is pruned from 10cm above ground level every year. Fruit yield is low (2- 4 kg/bush) in comparison to other fruit crops depend on management practices.

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 wildly 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, foot hills of J & K, U.P., Uttarakhand and Arrawali hills, Mount Abu (Rajasthan). In karonda plants, thorns are found and is 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.

Carissa species are mainly propagated by seeds but the seedlings are slow in growth, variable and are ordinarily not ready to plant until about 2 years old. The other drawback with seeds is that they are recalcitrant, which hampers the availability of planting material throughout the year. The other methods of propagation such as hard wood stem cuttings in open nursery, semi-hardwood stem cuttings under mist, softwood cuttings with the use of auxins under mist, air layering, stooling and grafting have been tried in the past but with variable success. The above methods are cumbersome, time consuming, labour expensive, weather dependent and produce limited number of plants per unit time to meet the growing demand for planting material of superior types. The soft wood cuttings planted under mist condition have found very success to raise plants under arid conditions. Rooting in soft wood thin cuttings was 100% under mist. As *Carissa* is planted at closer spacing and requires large number of plants per unit area, some alternative method is

required to produce large number of uniform plants. Hence in order to remove this major constraint in increasing area under *Carissa* cultivation and to protect the valuable germplasm from being eroded, micro-propagation can be tried.

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. Some promising clones have selected in Maharashtra. These are K_1, K_2, K_3 (Joshi *et al.*, 1986). At MPKV, Rahuri, promising clones as No. 3, 12, 13 and 16, have been identified (Karale *et al.*, 1989). At GBPUAT, Pantnagar, three clones have been selected and named as Pant Manohar, Pant Sudarshan and Pant Suvarna. These varieties are of big fruit size and high yield. It is generally planted on farm/ orchards boundary and it is very important plant for live fencing. It is evergreen shrub or small tree and attain height of 3 to 6 m when allow to grow. The species is thorny bush commonly found in degraded areas and ideal for use in hedges. A promising genotype of Karonda (CHES K-1) has identified at CHES, Godhra which is red colour fruit type and high yield potential.

Keeping in view, fast growing, drought tolerance and high yielding genotypes should be identified. It is susceptible to frost/low temperature; hence, frost tolerance types should be identified for hot arid regions.

Tamarind (*Tamarindus indica*)

Tamarind (*Tamarindus indica* L.) is an excellent tree for social forestry, agro-forestry, wasteland development and dry land horticulture. The tree assumes great significance due to its multifarious uses and capacity to withstand adverse agro-climatic conditions. The pulp of the mature, ripe fruit has considerable export value in many parts of the world.

There are several types of tamarind. They can be broadly grouped under three types based on fruit size and shape, colour of pulp, taste etc., as follows.

Tamarinds in the America are of the shorter type. Paulos (1975) recognized a tamarind type known as "Valakatchi" which bears long and rectangular pods as against some other types, which produce short and cylindrical pods. Karale (1998) reported that tamarind pods vary considerably in size and shape and variability in yield of pods and quality is found. Many are sickle shaped while some have straight long pods (16 to 22 cm) while others were with short pods. Seeds also exhibit a wide range of variation in shape size, colour and the ornamentation of the seed coat.

On the basis of pulp colour

There are two distinct phenotypes of tamarind based on mainly their pulp colour.

1. The yellow or brown pulp type turning dark brown on storage. It is harvested after full maturity.
2. The reddish pulp type is locally known as *"Raktichinch*". The term red type covers the various shades of pink pulped fruits. The red type is sweeter than brown (common) type because it has lower content of free acids and is generally harvested when fruits are immature and green. It is mostly prefered for making preserves. A high yielding Red type (*Yogeshwari variety*) has been released by Marathwada Agricultural University, Parbhani, Maharashtra.

On the basis of organoleptic taste

The cultivated types could be broadly classified into two groups namely sweet and sour types.

Sweet type: The ripe fruits of this type have sweeter pulp coupled with less acidity and fruits are mainly used for dessert purpose (Karale, 1998). Makham Waan, Secthong breed, Manila sweet are few cultivars found mostly in South East Asia (Thailand). A sweet type viz., No. 263 has been located by MAU, Parbhani.

Sour type: It is highly acidic in taste and pulp is commercially marketed. The tamarind variety `Pratisthan' released by Fruit Research Station, Aurangabad is a sour type and is reported to constitute of 61 per cent pulp, 12 per cent seed and 27 per cent shell. The sour type selections `Urigam' and `Cumbum' (good yielder) are popular in Tamil Nadu. A high yielding sour type PKM-1 (Periyakulam-1) has been released during 1992 from Horticulture Research Station, Periyakulam, Tamil Nadu . This cultivar is preferred for its early bearing habit and claimed to be suitable for high density orcharding (160 plants/acre against 40 plants/acre under conventional planting). Patil *et al*, (1997) reported high yielding elite types DT-1 (500 kg) and DT-28 (450 kg) from University of Agricultural Sciences, Dharwad.

Trees of outstanding merit are to be selected after a thorough survey in the tamarind growing regions. The selected trees should have higher yield potential, excellent fruit quality and better performance for precocious and regular bearing. The fruits should contain thicker pulp with less seeds, yellow or dark red pulp colour with extra white endocarp (locally known as *phool patti*) coupled with high acidity are desirable attributes of tamarind pulp (Karale *et al.*, 1997). The average composition of the pod is 55 per cent pulp, 34 per cent seed and 11 per cent shell and fibre. The selected types should be propagated vegetativly to maintain homogenity in the population and to reduce long juvenile phase and a mother orchard has to be established for preparing planting material.

Success of any breeding programme depends on the selection procedure adopted. The characters under selection should present in high heritability. Genetic analysis reveals wide range of variability among the economic traits. Heritability and genetic advance was higher for mean fruit weight, pulp content and pod girth.

Estimation of genetic divergence among 282 genotypes at 8 different agro-climatic locations revealed high variability for 18 characters. In all 8 principal components accounted for 80 per cent of the divergence. Pulp yield/tree was the most important character contributing to divergence followed by tartaric acid content. Pulp yield/tree ranged between 14.6 and 99.6

kg/tree while seed yield was 3 to 87.5 kg. The range of tartaric acid was 1 to 17.8 kg/ha.

A promising line have been identified and released at Institute level as Goma Prateek from CHES, Godhara, Gujarat. Fruit yield /plant is 58.5kg during 9th year of fruiting under rainfed conditions.

Karale (1998) carried out detailed study on 37 seedling originated genotypes and observed high heterozygosity and large variation with respect to pod shape, size, fruit quality and productivity. Many were sickle shaped while some had straight long pods (16 to 22 cm). The extra white endocarp membrane locally known as "*phool patti*" fetches more price and is an important quality character in tamarind trade. Further, he reported that there was not much difference in respect of TSS content of the pulp among the sweet, sour and red types. But the colour of pulp and seed varied among the types and within the types also. The pulp colour varied from reddish brown to different shades of black and sweet types recorded medium values for various physical characters. Based on positive attributes T-1, T-16, T-22, T-26, T-28, T-29 in sour (brown pulp) type, TR-1 in red pulp type and TS-1 and TS-2 in sweet pulp type were selected as elite types.

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, monkey fruit, curd fruit and kathabel 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, Palamu 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.

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 hiccough, 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.

Biotechnological approaches for improvement of arid fruit crops

Biotechnology is emerging as a powerful tool for crop improvement. Biotechnological approaches like gene transformation and somaclonal variation are attractive as they make possible a great range of improvements to varieties in a short period of time with little or no change in the genetic makeup of otherwise acceptable variety. Application of biotechnological tools in crop improvement programmes can be effective in three different complementary ways: speeding up the process of conventional breeding, creating genetic variability through tissue culture, and evolving novel genotypes through recombinant- DNA (r-DNA) technology (Chopra and Sharma, 1991). Somatic hybridization approach helps in generating cybrids by fusion of two sexually incompatible species. In developing new fruit varieties, biotechnology has two main applications: (1) transfer of desirable genes from quite distant living being, and (2) assist the conventional breeding programmes by reducing the time required for developing a variety and the number of progenies to be raised in the field. Genetic engineering enables to add any gene from any living organism including bacteria. Moreover, biotechnology makes it possible to transfer specific genes to a crop variety in one step, avoiding several back-crossing that is often followed, which is very difficult and time consuming and sometimes impractical because of perennial and heterozygous nature of many of the arid zone fruit crops. Anticipated changes in climate and its variability, particularly extreme temperature and changes in rainfall patters are expected to make crop improvement even more crucial for food production the biotechnological approaches such as molecular breeding and genetic engineering and their integration with conventional breeding to develop crops that are more tolerant of abiotic stresses (Varshney *et al*,2011). Biotechnology is a viable option for developing genotypes that can perform better under harsh environmental conditions. Biotechnology approaches have the potential to enhance crop production under different stress conditions.

The steps involved in transfer of foreign gene include: (1) selection and isolation of gene of interest from the appropriate living organism, and (2) gene transfer to target tissue capable of regeneration. Transformation could be achieved either by using Agrobacterium vector or electroporation microinjection. Although methods for DNA delivery into plant cells are well standardized, unpredictable transgenic expression and its subsequent stability in the new background limit the practical transformation of many plant species. Recombinant DNA gene transfer, embryo manipulation, plant regeneration, cell culture, monoclonal antibodies and bio processed engineering. These techniques can transform idea into practical application, viz. certain crops can be genetically altered to increase their tolerance to certain herbicides. Biotechnology offers new ideas and techniques applicable to agriculture and also develops a better understanding of

living system of our environment and over selves. It has a tremendous potential for improving crop production.

Conventional breeding has several limitations among others; it is time consuming, difficulty of raising large population and poor understanding genetics of several traits. Micro propagation technology ensure true to type, rapid and mass multiplication of plants that possesses special significance in vegetatively propagated plant species. Research in genomics allows high- resolution genetics analysis for physical mapping and positional gene cloning of useful genes for crop improvement. Molecular (DNA) markers help in precise characterization of germplasm, construction of saturated linked maps and DNA fingerprinting of crop varieties. Molecular markers are now increasingly being used for marker- assisted gene pyramiding and alien gene introgression. Current research, involving large scale DNA sequencing, microarrays and robotics, is heading towards gene revolution and nanobiotechnology (Mendeley, 2010). Hence, genome mapping, aimed at molecular markers tightly linked to the traits under selection, is particularly important in fruit tree species in permitting early selection of the most interesting genotypes. Molecular markers based on PCR technology, such as RAPDs, AFLPs and SSRs have been found more efficient than markers such as RFLPs and isozymes in characterizing genotypes. Sivalingam et al, (2012) characterized twenty two germplasm accessions of Cordia myxa collected from Rajasthan through morphological and RAPD markers. In their study, out of 50 random decamer primers used for random amplification (RAPD), 25 were polymorphic. Average polymorphism resolved by these markers among these accessions was 69.8% with an average polymorphic information content of 0.43. Genetic diversity revealed by Jaccard's co-efficient was between 0.44 and 0.94, and three major clusters were identified among these accessions by phylogenetic analysis using NTSYSpc-2.02e software. RAPD markers associated with leaf size and pulp:stone ratio were also identified. This study shows the existence of high genetic diversity among these accessions.

Moisture stress and high temperature tolerance are the traits that are to be addressed often in arid fruit crop breeding. In response to moisture stress heat shock proteins have been identified in some plants. Modification of heat shock proteins in the cell via genetic engineering has been done in herbaceous plants indicating a possible use of this strategy for increasing thermal tolerance in arid fruits (by use of appropriate promoters). Many of the horticulturally valuable varieties or rootstocks often show very poor rooting ability. Rooting can be improved by inoculating Agrobacterium rhizogenes by wounding the basal part of in vitro micro cuttings.

The concentrated efforts and standardization of several techniques like induction of somoclonal variation and in vitro selection, somatic embryogenesis, in-vitro regeneration, protoplast culture, genetic transformation in arid fruit crops is necessary if we have to see biotechnological tools benefiting this group of fruits production.

In conclusion, it could be mentioned that despite several limitations and problems associated with breeding of arid fruit crops by conventional methods, novel biotechnological approaches will not replace the former approach, but it will effectively compliment the traditional breeding methods. Conservation of genetic resources of arid fruits are very essential for future crop improvement programme.

References

Anonymous. 2011. Improvement of Arid Zone Fruits In. Biennial Report, Group Workers Meet, AICRP on Arid Zone Fruits, CIAH, Bikaner pp. 87-96.

Anonymous. 2008. Annual Report, AICRP on AZF, CIAH, Bikaner.114p.

Anonymous, 2011-12. Annual Report, CIAH, Bikaner,118p.

Chopra, V. L. and Sharma R. P. 1991. Biotechnology in crop improvement. *Current Science*, 60 (9 & 10): 543-545.

Choudhari, K.G. and Shirsath, N.S. 1976. Improvement of pomegranate (*Punica granatum* L.) by Selection. *South Indian Hort*., 24:56-59.

Dhandar,D.G. and Singh,R.S.2004. Germplasm collections of Arid zone fruits in India, AICRP on AZF, CIAH, Bikaner 35p.

Dhillon, B.S. and Saxena,S. 2005. Plant Genetic Resources in SAARC Countries: Their Conservation and Management,SAARC, SAIC,Dhaka, Bangla desh,pp.337-403.

Jalikop, S.H., Tiwari, R.B. and Sampath Kumar, P. 2002. Amlidana- A new pomegranate hybrid, *Indian Horticulture,* 47(2):22-23.

Joshi, G. D., Prabhudesai, V.G. and Salvi, M.J. 1986. Physicochemical characteristics of Karonda (*Carissa carandas* L.) fruits. *Maharashtra J. Hort.*, 3(1) : 39-44.

Karale, A.R., 1998. Status Report on "Improvement of Tamarind by selection" presented at Research Workers Group meeting of AICRP on Arid Zone Fruits held at CCS, HAU, Hisar, 14-16 Oct.1998.

Karale, A.R., Wagh, A.P., Pawar, B.G., Shete, M.B. and More, T.A. 1999b. *J. Maharashtra Agric. Univ.* 24(3) : 319-320.

Karale, A.R., Keskar, B.G.; Shete, M.B., Dhawale, B.C., Kale, P.N. and Chaudhari, K.G. (1989). Seedling selections of Karonda (*Carissa carandas* L.). *Maharashtra J. Hort.*, 4 : 125-29.

Kaushik, R.A. and Dwivedi, N.K. 2004. Genetic diversity in *lasoda*. *Indian Horticulture* 1: 27.

Lal, G. 2002. Evaluation of bael (*Aegle marmelos* Correa) germplasm in semi-arid regions of Rajasthan. *Curr. Agric.*, 26 (1-2): 127-129.

Mehta, S. S. and Singh,H.P.2003.Aonla in India, Aonla Growers Association of India,Salem, Tamil Nadu 268pp.

Mendeley, 2010. Biotechnology and crop improvement. *Jour. Crop Improvement,* 24 (2): 153-217.

Misra, K. K., Singh, R. and Jaiswal, H.R. 2000. Performance of *bael* (*Aegle marmelos*) genotypes under foothills regions of Uttar Pradesh. *Indian J.Agric. Sci*., 70(10): 682-683.

More, T.A. and R. S. Singh 2008. Conserving Biodiversity in different areas, The Hindu Survey of Indian Agriculture, Hyderabad, pp50-54

More,T.A., Samadia, D.K., Awasthi, O.P. and Hiwale, S. S. 2008.Varieties and Hybrids of CIAH, Central Institute for Arid Horticulture, Bikaner, p11.

Muralidharan, C.M., Tikka, S.B.S. and Piyus Verma 2008, Date palm cultivation in Kachchh, Tech. Bull.No. 02. S.D. A.U., Date palm Centre, Mundra, Kachchh, 36p.

Patil, V.S., Madalageri, M.B., Sulikeri, G.S. and Naik, R. 1997. In. *Abstract. Proc. Nat. Symp. on Tamarindus indica* L. held during 27-28, June at Tirupathi. p. 9.

Paulos, D. 1975. *Agril. Agro. Ind. J*,. 8 : 35-37.

Pundhir, J.P.S. 1987. Studies on growth flowering and fruiting behaviour of Lehsua (*Cordia dichotoma* Forst.), Ph.D. Thesis, Sukhadia Univ., Udaipur.

Rai, M., Dwivedi, R. and Gupta, P. N. 1991. Variability and potentials of identified germplasm of *bael* (*Aegle marmelos* correa.). *Indian Jour. Pl. Gen. Resources*, 4(2): 86-92.

Saini,R.S., R.A.Kaushik and S.Singh (2002) Research note on the evaluation of Lasora (*Cordia myxa*) germplasm for vegetative growth under semi-arid conditions. *Haryana J.Hort. Sci*.,31:62-63.

Shukla, A.K., Bhargava, R., Singh, R.S. and Sharma, S.K. 2011. Germplasm resources and Production Technology of Ber. Tech. Bull. No. 41, CIAH, Bikaner, p 34.

Shukla, A.K., Dhandar,D.G., Vashishtha, B. B and Umamaheshwari, C. 2004. New Promising Ber varieties, *Indian Horticulture*, 49 (3):36.

Shukla, Anil Kumar, Shukla, Arun Kumar and Vashishtha, B. B. 2004. Fruit Breeding Approaches and Achievements. International Book Distributing Comp, Charbagh, Lucknow, U.P. 342p.

Singh, A.K., Singh, S., Singh, R.S. and Sisodia, P. S. 2011. The Bael A potential underutilized fruit for future. Agro-Tech Publishing Academy, Udaipur. p 104.

Singh, D. B. and Singh, R. S. 2006. Diversity of wild Pomegranate in Himachal Pradesh. *Progressive Horticulture*, 38(1): 49-52.

Singh, H.K.; Srivastava, A.K., Prasad, J. and Dwivedi, R. 2009. Descriptor of bael (*Aegle marmelos C*orrea.) AICRP on Arid Zone fruits, NDUA&T, Faizabad, p.23.

Singh, R. S., Bhargava. R., Vashishtha, B. B. and Ramdevputra, M.V 2009. Genetic diversity in date palm (*Phoenix dactylifera*). *Current Agric.*, 33: 67-72.

Singh, R. S., Hare Krishna, Bhargava, R. and Sharma, B.D. 2012. Exploitation of Underutilized horticultural crops for sustainable production compendium of winter school, CIAH,Bikaner, 282p.

Singh, R**.** S., Sharma, B.D., Bhargava, R. and More, T. A. 2011. Introduction and evaluation of Anardana type pomegranate under hot arid conditions. *Acta Hort*., 890: 239-242.

Singh, R.S. and Vishwanath 1991. Shushka Kshetra mein labhkari lasoda lagayein. Phal-Phool, April-June issue, ICAR,New Delhi, p. 8-9.

Singh, R.S., Vishal Nath and J.C. Tewari 1996. Lasora- a promising fruit tree for arid ecosystem. *Deco Mirror*, 3(2): 5-11.

Sivalingam, P. N., Dhurendra Singh, and Sarita Chauhan.2012. Morphological and molecular diversity of an underutilized fruit crop-Cordia myxa L. germplasm from the arid region of Rajasthan, India." *Genetic Resources and Crop Evolution*, 59.2 : 305-316.

Srivastava, A.K. Singh, H.K and Singh, I. S. 1998. Genetic diversity in Bael (*Aegle marmelos* Correa) *Indian Horticulture.*

Varshney, R. K., Bansal, K. C., Aggarwal, P. K., Dutta Swapan K and Craufurd, Peter,Q. 2011. Agricultural biotechnology for crop improvement in a variable climate: hope or hype?. *Trends in Plant Science*, 16(7): 363-371.

Vishal nath, , Kumar, D. and Pandey, V. 2008. Fruits for the Future, Vol. 1: Well Versed Arid and Semi-arid Fruits. Satish Serial Publishing House, Delhi. P. 512.

Vishal Nath, Pandey, D. and Das, Bikas. 2003. Diversity of Bael (*Aegle marmelos* Correa) in East Central India, *Indian Jour. Plant Genetic Res., 16:85-89.*

Yadav, P.K. and Goel, M. 2006. *Lasoda* (*Cordia dichotoma*). Advances in arid horticulture, Vol-II Production technology of arid, semiarid fruits. By Saroj, P.L., Awasthi, O.P. (eds) International Book Distributing Co, Lucknow, pp. 305318.