Integrated Pests Management of Arid Fruit and Vegetable crops

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Suitable genotypes of underutilized fruit crops for pest management

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Climate change has become one of the biggest challenges for the sustainable crop production. Prolonged droughts and desertification are among the issues faced by Indian hot arid zone where the rural poor and smallholders are most heavily affected. People have to survive in these types of conditions; thus their crops need to withstand such harsher calamities viz., drought, high temperatures and poor soils (Kumar et al. 2018). Underutilized fruit crops are gaining increasing interest in the world, in particular cactus pear (*Opuntia ficus indica* (L) Mill.), lasoda (*Cordia myxa*), phalsa (*Grewia subnaequalis)*, karonda (*Carissa canjesta*), mulberry (*Morus* spp.), ker (*Capparis decidua)*, pilu (*Salvadora* spp.) etc. because of their unique adaptation characteristics which provide resilience to the harsh ecological conditions.

Production technology of lasoda, *Cordia myxa*

Arid regions lie under the category of wastelands which are not being used to their fullest potential. Among arid crops, Lasoda is very suitable crop for cultivation in such type of climate. Lasoda is such type of crop which can be grown successfully with minimum agricultural input in hot arid regions. Lasoda generally called as cherry of the desert. It is also known by several other names such as gunda, lehsua, goondi, glue berry (due to mucilaginous pulp), assyrian plum, Indian cherry (Samadia 2007). It is an underutilized, multipurpose, herbal fruit tree distributed in the arid and semi-arid regions. The origin of this tree is suspected to be from the eastern Mediterranean region to eastern India. It is an introduced tree in tropical Asia, Africa, Australia and the Americas and distributed in the western tropical Africa to Italy, South-East Asia, Australia, Europe and tropical Americas. In India, it is found mostly in the northern part and is abundantly distributed and naturally growing in the north-western region (Sivalingam et al. 2012). It is a medium sized, broad leaved deciduous tree. It has great capacity to tolerate drought and hence quite widespread in arid and semi arid regions of north India. Its habitat starts at about 200 m above mean sea level in the plains and ascends right up to a height of about 1500 m in the hills. Most of the research work reported on this crop is from natural occurrence. From last two decades it is being cultivated as a commercial crop in arid and semi arid regions of India and other isoclimatic parts of the world for fruits and culinary purposes. Utilization of different plant parts for ethno-botanical purposes is an age old practice. Efforts are now being made to select the high yielding desirable genotypes and to develop its clonal propagation method through conventional as well as through biotechnological tools.

Nutritive value and uses

Being a multipurpose plant, it has long been associated with health, nutrition and other diversified uses. Almost all parts of it are used for various purposes. Immature fruits can be used as vegetable or for making pickles. Mature fruits of lasoda are very nutritious being rich in carbohydrates (12.2 g/100 g of edible portion), total ash (2.13%), vitamins and minerals, with high medicinal values and can be used as an anti-helmenthic, diuretic, demulcent, expectorant and anti-tumorigenic and used in preparation of Ayurvedic medicine. Leaves are used as fodder for goat, sheep and cattle and making pattal (trays/plates). Wood is used for making ornamental furniture, house-posts, agricultural implements etc. In addition, this tree tolerates frost and drought (Sivalingam et al. 2012). The immature fruits of gonda are used as vegetable, pickled with raw mango and can be dehydrated for use in off season. The fruits and other plant parts are used in curing various ailments viz. skin diseases, dropsy, dysentery, dyspepsia, cholera and headache etc. The fruits are astringent, anthelmintic, diuretic, demulcent and expectorant.

The fruit contains about 80% pulp; the pulp contains per 100g dry weight: ash 6.7 g, crude protein 8.32g, lipid 2.2 g, crude fibre 25.7g and carbohydrates 57.08 g and 281.4 k calorie (Aberoumand, 2011).

Genetic diversity and varietal improvement

In India, there is lot of genetic variability present in existing lasoda plantations especially *C. myxa* of Rajasthan, Haryana, Gujarat, Madhya Pradesh, Himachal Pradesh and Uttar Pradesh. However, there is few named cultivar/variety released for cultivation. In Rajasthan big fruited type is recognized as 'Thar Bold' from ICAR-CIAH, Bikaner, 'Maru Samridhi' from ICAR-CAZRI, Jodhpur, 'Karan Lasoda' from Jobner. In general, two types of plants such as big fruited and small fruited are found growing and sold by nurserymen. Small fruited types locally called as goondi and much liked by rural people of Rajasthan and Gujarat. Though the importance and usage are known, this fruit tree has not yet been utilized as an orchard crop. It can be grown in non-cultivable or wastelands, backyards, on roadsides and farm boundaries. The reasons for its under-utilization are the lack of ideal genotypes for cultivation and no commercial exploitation on value added products for consumer preference (Sivalingam et al. 2012). Conservation and understanding the genetic diversity of this underexploited fruit crop are primary requirements for the identification of superior genotypes for its exploitation and improvement on a commercial basis. Recently, ICAR-CIAH, Bikaner has identified one genotype of lasoda which is big fruited, heavy bearer and released at institute level as 'Thar Bold'.

There are very few reports available on determination of genetic diversity of *Cordia myxa* using DNA markers. Therefore, the genetic diversity of *C. myxa* germplasm lines maintained at the gene bank of ICAR-CIAH, Bikaner was ascertained by morphological and Random Amplified Polymorphic DNA (RAPD) markers by Sivalingam et al. 2012. They morphologically characterized 10 year-old trees for 17 traits indicated wide variations among the accessions tested. Overall, AHCM22 was found to be a superior germplasm line for most of the horticulturally useful traits among the accessions tested as it had higher percent of fruit set, pulp:stone ratio and fruit weight. High significant positive correlation was obtained between leaf, fruit characters and pulp:stone ratio. 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. They concluded that there is high genetic diversity existed among these accessions.

Soil and climatic conditions

It can thrive well on neglected, low fertility, sandy swampy saline alkaline soils and hence can be best used for afforestation of the wastelands. Lasoda plants are very hardy and can be grown in almost all types of soils. However, moist sandy loam soils are the most suitable for vigorous growth and productivity. It can tolerate salinity up to certain extent. If the soil is rich in organic matter plant produces greater yield. Water logged soil is also not suitable for its cultivation. Lasoda thrives well under tropical as well as sub-tropical climates up to an elevation of 5000 feet. It needs warmer climate and is susceptible to frost. But can tolerate 0 °C temperature for some days and few weeks. It can withstand drought to a very greater extent and can tolerate high temperature up to 48 to 50°C during the summer months especially in arid region of Rajasthan. It thrives well in the areas of having average rainfall of 250-300 mm.

Plant propagation

Lasoda is propagated by seed as well as by vegetative means. Due to release of very few improved

released varieties (Thar Bold from CIAH, Maru Samridhi from CAZRI, Karan Lasoda, Jobner), it is generally propagated by freshly extracted seeds from ripened fruits by the nurserymen. Since it is a cross pollinated crop, greater variability is found in the population derived from seed propagation. Therefore, selection of high yielding genotypes along with other desirable attributes from seedling population and perpetuation of the same by clonal propagation is the best strategy for improvement of this crop. Clonal propagation through patch budding has been standardized at ICAR-CIAH, Bikaner and budded plants are supplying to farmers for cultivation. Based on big fruit size, high fruit yield potential and other desirable attributes, one elite genotype i.e. 'Thar Bold' was identified at institute level for commercial exploitation

Transplanting

Lasoda is transplanted at 5-6 meter spacing in square system in well prepared 1 x 1 x 1 m sized pits filled with the mixture of soil, 15-20 kg FYM and 50 g Methyl Parathion 5 % dust. Application of organic manure is beneficial for the establishment and moisture retention. Pits should be dug one month prior to transplanting. Transplanting should be done during rainy season, *i.e*. July to September. *In situ* planting and patch budding at appropriate time is successful method for rain fed fruit production of *lasoda*.

Training and pruning

Training is essential to develop a good framework of the plant. Four to six branches having good crotch angle are allowed on the trunk at a height of 1 m from ground level. *Lasoda* plant does not require regular pruning. However, suckers emerging from main trunk or rootstock, undesired, weak and diseased branches should be pruned. Manual or chemical defoliation through potassium iodide (KI) to induce early flowering and fruiting is beneficial practice in *lasoda* orchards for taking economic yield.

Manuring and fertilization

Application of well rotten farm yard manure (FYM) before flowering and fertilizers including N, P and K after pruning and fruit set in split doses helps in good vegetative growth and fruiting. Application of 100 g N, 125 g P_2O_5 and 50 g K_2O per tree should be done to achieve vigorous growth and fruiting in arid regions, besides this 10 kg FYM per plant during monsoon season. Application of 20-30 kg FYM and 1.00 kg diammonium phosphate to five years old plant is found beneficial to increase fruit yield in semi-arid areas.

Water management

In situ water harvesting in rain fed, arid and semi-arid regions by providing 5-10 % slope in two directions of plants is found suitable to increase productivity of the plants. Though *lasoda* is drought hardy plant but at initial stage, irrigation is necessary to young plants after transplanting at an interval of about 15-20 days during winters and 8-10 days during summers. Saline water (3-6 dSm^{-1}) can also be used to irrigate *lasoda* orchards in sandy soils.

Flowering and fruiting

*F*lowering commences in lasoda during the months from March-April. Flower is short, stalked, bisexual and appear in loose corymbose cyme. Inflorescence is generally terminal is usually white in colour. Being a bisexual plant, both male and female flower found on same tree. The percentage of fruit set was found to be very low. Generally fruits come in bunches and bear on terminally, axillary and even from main branches and trunk called cauliflorous bearing.

Fruits of lasoda are picked at horticultural maturity for their culinary exploitation such as pickle, vegetable etc. Fruits are ready for picking by the middle of May month. Fruits should be picked manually when colour is still green and pulp is properly formed. It is better to pluck the fruits along the fruit stalk. Yield differs with tree age, climate and management practices followed. Lasoda tree starts producing fruits after 4-5 years of transplanting. Young plants produce 5-10 kg green fruit/ plant while a developed

plant yields about 50 kg fruits, which can be increased by adopting improved orchard management practices up to 100 kg per tree. In normal rainfall conditions it gives 100-150 kg yield per tree which is also depends upon the genetic potential of genotype.

Postharvest handling, processing and value addition

Bruised or injured fruits are sorted out after harvesting. Healthy fruit bunches are packed in bamboo baskets or gunny bags and send for marketing. For distant transportation, it is always better to pack them in bamboo baskets. Fruits can not be stored at room temperature for longer period as they turn yellow becoming unsuitable for cooking and pickle purpose.

Plant protection

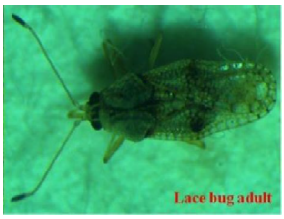
Lasoda plant is an excellent host for lac insect, which may cause economic loss. Leaf gall midge cause damage to leaves which can be seen in the form of pustules on the under surface of leaves. Borer also attacks on fruits. These can be controlled by spray of 0.05 % monocrotophos or any other systemic insecticide. *Eriophyes cordiae* mites also attack on *Cordia dichotoma*, which result in leaf gall formation.

Insect-pests

According to the National Tree Seed Project (1999), insect damage on *Cordia africana* seeds was 45%, 30% and 20% from Sekoru, Arjo and Wondo Genet places, respectively. Tibebu (2002) studied pre-dispersal insect seed predators on seeds of these two tree species, 10 and found 20% of *Cordia africana* seeds collected from Sekoru, and 8-10% of seeds collected from Denbi, Jimma and Arjo places.

Tingid bug, *Dictyla cheriani*

Haldhar and Singh (2014) reported that infestation of *Dictyla cheriani* on Indian cherry (*Cordia myxa*), was first noticed in 2010 at Bikaner, Rajasthan. The maximum incidence was observed in October (51.67% on bold & 76.67% on small seeded plants) and minimum in January (11.67% on bold & 21.67% on small seeded plants). The number of this lace bug ranged between (0.5 to 8.8 on bold & 4.5 to 25.97 on small seeded plants) nymphs and adults per leaves. The lace bugs were found to be aggregated on the leaves of the plants. During a survey of the natural vegetation, the population of this pest was found to be higher on small seeded plants than the bold seeded plants. The lace bugs sucked the sap from newly emerging leaves and young branches, which led to the leaves turned yellow and suppression of growth of the tree through drying of leaves and young branches (Haldhar and Singh 2014).



Management

Provide proper cultural care so plants are vigorous. If damage has previously been intolerable, monitor plants early during subsequent seasons. Take action when populations begin to increase and before damage become extensive. Provide adequate irrigation and other care to improve plant vigor. Prune out damaged foliage if the discoloring is intolerable and relatively localized. Do not remove more than a small percent of a plant's branches during one season and use good techniques so that pruning does not injure plants, such as by exposing inner branches to sunburn. Almost any insecticide will control lace bugs if it is sprayed directly onto the insects. Azadirachtin (BioNeem), insecticidal soap (Safer), narrow-range oil (Green Light, Volck) and neem oil sprays temporarily control lace bugs if insecticide thoroughly covers the underside of leaves where adults and nymphs occur. Imidacloprid 17.5 SL can be applied as a foliar spray for controlling of this pest.

Diseases

Leaves of lasoda trees are often seen infected by fungal diseases. Trees should be sprayed with copper fungicide once before initiation of new growth and 1-2 times during active growth period and fruit development. Pink disease (*Corticium salmonicolor*) caused dieback and canker on branches and stems. High humidity, shade and precipitation are important factors in spreading the disease. For controlling one can follow these tips: Cut die-back portion then paste by copper ox chloride at the rate of 0.3%. Curse and scorch canker at partly and paste them with copper oxychloride 0.3%. Spray of Bordeaux mixture 1% is also beneficial.

Production technology of cactus pear, *Opuntia ficus indica*

Cactus pear can be grown on land where no other crops are able to grow; it can be used to restore degraded land. It is the only crop that can be relied on when everything else fails. Cactus plant and its cladode, fruits are popularly known by several names such as prickly pear, cactus pear, Indian fig opuntia, Barbary fig, spineless cactus, nopal cactus *etc*. The young cladode is called *nopal* and the fruit is *tuna*. Nopal word is especially known for its culinary exploitation of cladodes in the form of vegetable, salad, pickle *etc*. Now days many of the cactus are ornamental plants which can be grown in a small pot. The cactus pear plants though shallow rooted but have capacity to absorb and store water in its parenchyma even under unfavorable climatic conditions due to high mucilage production in both cladode and fruits. Besides, peculiar adaptations to water scarcity and high as well as low temperature is because of reduced leaf tissues and cuticular wax covering of cladodes and fruit surfaces. Even today cactus pear is treated as underutilized crop in India, though it has multiple utility (Saroj et al. 2017). The value added products of cactus pear could also supplement to nutritional security and human health. The succulent vegetative parts are called as pads or cladodes which are modified stem (Kumar et al. 2017).

Soil and climatic requirements

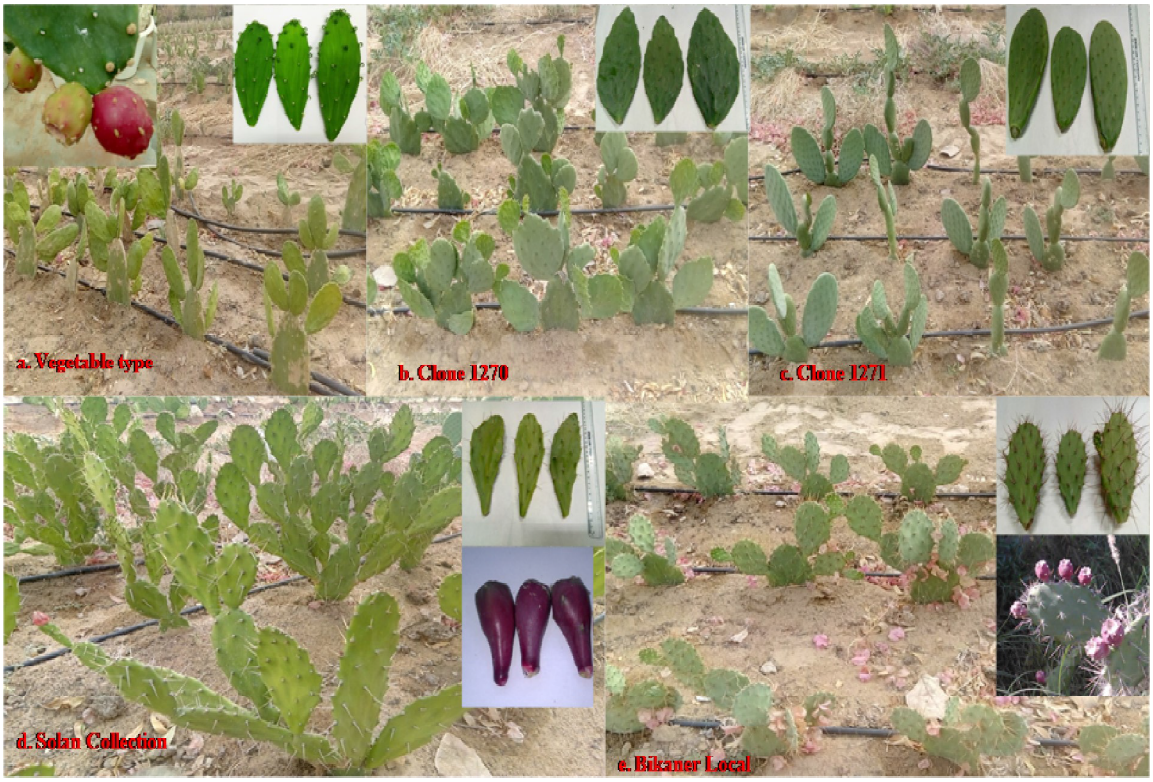
The ideal conditions for cactus pear cultivation are sunny warm summer and cool dry winters where temperature does not fall below -5^{0}C during spring and early summer and annual precipitation between 300-600 mm. Cactus has wide range of adaptability and can grow in any types of soils. It grows in different types of soils in the natural habitat. Basically, cactus pear is a drought resistant crop and thieves well in deserted and semi-arid areas having sandy soils. Higher rainfall is unsuitable for cactus cultivation. Generally, it is susceptible to frost but some clones are also found to be cold hardy in nature. It can survive and perform well under alkaline, heavy, gravely and rocky soils also have option for acidic soils. Many cacti thrived well in harsh, dry, sandy arid and semi-arid environments.

Suitable genotype and site for cultivation

The selection of suitable cactus genotype/ cultivar depends upon the purpose *i.e.* vegetable, fodder or fruit for which cultivation is being done. ICAR-Central Institute for Arid Horticulture (ICAR-CIAH), Bikaner has identified 6 promising genotypes of cactus pear which are suitable for vegetable (nopal production), fruit and fodder and 3 spiny genotypes, which are prolific fruit bearing type. Formal orchards with spineless (vegetable type) cultivars/varieties should be considered only close to household where human presence provides sufficient safety to damaging pests such as wild animals as well as domestic ruminants and squirrels. Vegetable type genotype is easier to handle and better for human and animal consumption. Low cost green house and net houses are also suitable for safe cultivation of this genotype. Plantations in isolated areas are more practical with spiny varieties (Kumar *et al.* 2018).

Planting season

Cactus can be planted in the field during July– September and February- April. But in green house it can be planted round the year. Maximum plant survival was found where planted during July–September under field condition.



Notation a denotes genotype suitable for vegetable (spineless), salad, pickle, squash, animal feed, edible, fruit production; b. denotes, genotype suited for animal feed; c. denotes, genotype suitable for animal feed and biofencing; d. means, genotype suitable for biofencing and fruit production; e. denotes, genotype suited for fruit production and biofencing.

Propagation

Cactus pear is propagated vegetatively through mature cladodes of 5-6 months old during the months of February- April and July – September. In green house it can be propagated round the year. Curing of cladodes should be done after removal from mother plant. Keep the detached cladodes under shade for about two weeks so that proper healing and dehydration may take place for better conservation and establishment under field condition. Black polythene bags or small plastic pots are suitable for this purpose. Propagation medium plays key role in establishment and survival of cactus because it is well known that cactus is very sensitive to water logging condition. Therefore, selection of suitable medium is necessary. A proportion of Soil, sand and FYM (40:30:30) is the best medium for cactus.

Field planting

Physiologically matured cladodes of identified and selected vegetable type, spine less clone should be used for planting. Curing of freshly harvested cladodes should be done after removal from mother plant. Keep the detached cladodes under shade for a minimum of two weeks so that proper healing and dehydration may take place for better conservation and establishment under field condition. Before planting cladodes can be treated with fungicide such as bordeaux mixture or mancozeb @ 2g/liter water to protect them from rotting. Cactus pear spacing depends on its variety/ clone/ genotype, whether it is compact or spreading in nature. The pads should be planted upright in the field keeping 1/3rd lower portion in the soil. Various institutions have given several planting distances viz., 5 x 4 m, 4 x 3

m, 4 x 2 m, 3 x 3 m, 3 x 2 m and 2 x 1 m. But, We at ICAR-CIAH, Bikaner has adopted a closer plant spacing 1 x 0.6 m for vegetable type, spine less clone on drip irrigation method because it was reported that cactus can be grown successfully at a close plant spacing (Kumar et al. 2018).

Water management

Cactus pear is very sensitive to water therefore optimum irrigation should be provided during early stages of growth. Cactus plants do not irrigate immediately after planting. Light watering should be done after 2-3 days of planting and there after irrigation should be given at 10-15 days interval up to one year. Fully established plantation requires light irrigation for better yield. There is no need of irrigation in areas where summer rains are good because cactus has highest water use and rain use efficiency among other drought hardy crops. Monthly irrigation except during monsoon season was found beneficial for cladode growth and development.

Manures and fertilization

Nutrient requirement of cactus pear is low but nutrient deficiencies can cause great losses to plant health and economic yield. Winter application of manures and fertilizers has been reported very effective in obtaining new cladodes as well as fruits. Cactus pear responds very quickly to application of manures and fertilizers as we observed that application of NPK grade (19:19:19) 3-5 gram per liter was found beneficial in new sprouting of cladodes after every picking of cladodes/ fruits under green house condition. Cactus pear reacts very well to organic manures which also improve the soil structure, nutrient content and water-holding capacity. Generally, 6-10 tonnes per hectare well decomposed FYM is to be incorporated into the soil before planting. The application of 5 MT well decomposed Farm Yard Manure and 60:30:30 kg NPK per hectare at the time of planting for suitable growth of the cactus plantation. Application of 20 kg Nitrogen is useful in enhancing the new sprouting after every harvest for production of cladodes either for nopal or fodder purpose.

Flower and fruit development

In general flowering occurs in cactus pear species 2-3 years after planting. But in nopal cactus flowering and fruiting occurred even first year of planting under green house as well as field condition at ICAR-CIAH, Bikaner. Flower and vegetative bud initiation occur simultaneously on corner side of the cladodes. Flower production take place on cladodes of more than six month old mostly from terminally and sub-terminally also. Time required from vegetative bud initiation to nopal/ edible stage of cladode was recorded 15-20 days which weighed from 22- 46 g/nopal, while flower bud took 30-40 days and it required almost 75-90 days for ripening of fruits.

Harvesting and yield

Harvesting is mainly depends upon the purpose for which cactus pea is cultivated. Harvesting period and number of pickings is varying according to need of the cactus product. For the ease we have categorized it according to need of the cactus product here under. It has a very high yield potential. Tender nopals of cactus pear are harvested for vegetable purpose during the early stages of growth, when they reach 10 to 15 cm long and about average weight of 30 g/nopal. As the cladode ages the fibre content increases and become more difficult to process there after these are suitable for animal feed. Under greenhouse nopales can be harvested regularly at 15-20 days intervals with an average yield of 1.5 kg tender nopales per plant per year. Fruit yield mainly depends on climatic conditions, cultivar, plant age and management practices. Although, cactus pear started bearing of fruits after one year of planting but commercial yield is obtained after 4-5 years. The improved varieties yielded 10-12 mt/ha fruits and 10-150 mt/ha fodder per year. It can produce more than 20 tonnes dry matter per hectare per year and provide 180 tonnes of water per hectare per year stored in its cladodes, representing a cost-effective option for livestock watering. Vegetable clone 1308 can yield biomass production of 80–90 tonnes per

hectare per year (Kumar *et al.* 2018).

Pests, disease and disorders

Pests of economic importance

Several pests *viz.,* domestic ruminants, squirrels, insects, rodents, birds *etc.* have been found associated in damaging the cactus pear. A number of insect species such as ants, bugs, thrips, moths, beetles, flies, scales etc. cause damage to opuntia world-wide. In India, spine less, vegetable type, less thorny fodder type genotypes are severely damaged by wild animals as well as domestic ruminants and squirrels. Therefore, formal orchards with spineless (vegetable type) varieties should be considered only close to household, where human presence provides sufficient safety to damaging pests. Phycitid moth (*Cactoblastis cactorum* Berg.) and cochineal insect (*Dactylopius opuntiale* Cockerell) are most damaging pests of opuntia. The other pests of economic importance are armoured scale and med fly whose larvae infest the fruits at a larger scale in many cactus species. At present phycitid moth is found all over the cacti growing areas of the world and causes severe attack and damage on young plants. Attack was observed only on cladodes but in acute cases it also damage fruits.

Cochineal bug, *Dactylopius opuntiale*

Cochineal bug is a major pest of cactus which causes death of the plant in acute condition. But it also reared in many countries for production of pink coloured dye. The economic importance of it can be understand that it was introduced in South Africa, Australia, India, Sri Lanka etc. in order to improve the dye industry. Cochineal bug causes damage to whole parts of the plant such as cladodes, fruits and stem. It appears like cotton scale and affected cladodes and fruits detached automatically from the plants either mature or immature. These cladodes and fruits fell down and loss their economic value.

Management

There was noticed that extreme temperature and sunlight reduced the infestation of the cochineal bug when severely attacked nopal cactus plants (vegetable type, spineless) was shifted from geen house to open condition at CIAH, Bikaner. The spray of imidacloprid 17.5 SC @ 0.5 ml/l of water at 15 days interval was found effective in managing of this insect. Although some bicontrol agents such as ladybird (*Exochomus flaviventris* Mader), Australian coccinellid (*Cryptolaemus montrouzieri* Mulsant) and a fungal pathogen (*Entomophtora lecanii* Zimm.) were found effective in controlling of the pest. Spraying of acephate chemical @ 2g/ litre at weekly intervals starting from early attack of the bug significantly contolled and killed the cochineal bug population and saved the nopal cactus plants under green house at CIAH, Bikaner.

Diseases and disorders of cactus pear

Cactus pear has high water content in its cladodes, that is why attacked by several dieases caused by fungi, bacteria, nematodes, yeast, viruses etc. which caused damage to plants and reduce the biomass and fruits yield. Physiological disorders are caused due to the environmental and nutritional imbalance, genetic causes and faulty agrotechniques resulting low production and productivity. The major diseases are bacterial spot, Armillaria root, stem and foot rot and wilt. An experiment was conducted by Nallathambi et al. (2005) on foot rot *(Phytophthora nicotianae)* in cactus pear genotypes under arid conditions and observed that this disease was major hindrance in establishment of cactus pear. They have reported that 23.5% foot rot incidence occurred in germplasm colections during the month of August and November and soil drenching with 0.1% Ridomil and dipping of cut ends of cladodes in fungicide at the time of planting found efffectinve in controlling of foot root.

Production technology of mulberry, *Morus spp*.

Mulberry is widely distributed in the temperate, subtropical, or tropical regions of the world and

can grow in a wide range of climatic, topographical, and soil conditions. The domestication of mulberry started several thousand years ago because of requirement for silk worm rearing. Considering that the silk trade has existed for a long time throughout the Old World and that mulberry is also cultivated for its fruit and for landscaping, its germplasm has been taken to many countries, and now it has a very wide distribution range. Mulberry is common all over India from temperate to tropical zones. *M. laevigata* is an important timber species of north-east and western Ghats. It is largely grown in the states of Karnataka, Andhra Pradesh, West Bengal, Tamil Nadu, Uttar Pradesh, Assam, Manipur *etc.* Although, the maximum utilization of mulberry is in Asia, this does not imply that mulberry cultivation is limited only to Asian countries. Mulberry is present on almost all continents and is used for various purposes, including its ornamental value in gardening and landscaping (Vijyan et al. 2012).

Nutritive value and uses

The ripe fruit of mulberry is highly appreciated for its delicious taste which is consumed fresh or after extraction of juice. Immature fruits are used for chutney preparation. Mulberry fruit is used to treat weakness, dizziness, tinnitus, fatigue, anemia, and incontinence. The dominant taste of the ripe fruit is sweet but usually with sub-acidic blend due to the high water content and low level of other flavouring ingredients. The flavour improves if the fruit is dried. The ripe fruits of mulberry contain 8-9% sugar and 1-2% acid. The ripe fruits of mulberry contain about 9% sugar with malic acid citric acid. Mulberry is also considered as "*Kalpa Vriksha*" as all the parts of the plant have many uses. Throughout the Asia, mulberry is highly appreciated for its delicious and thirst quenching fruits, which is consumed fresh, or in the form of juice or conserves. Further, it is essential to sericulture as the mulberry foliage is the only food for the silkworm (*Bombyx mori*). In India, most states have taken up sericulture as an important agro-industry with excellent results. However, its cultivation for fruit production is very low, despite its nutritive and functional food importance. By growing mulberry, a farmer obtains fodder, fuel and fertilizer (manure). Mulberry could be exploited as an 'energy crop' in cultivable, wasteland, low-lying areas, canal bunds, by roadsides and at fringe areas of the forest, etc. under various afforestation, watershed development and soil conservation programmes.

Genetic diversity and varietal improvement

Huge diversity exists in available germplasm pool of mulberry in India and abroad. Mulberry being perennial and out breeding tree, exhibit high degree of heterozygosis and often produces recalcitrant seed. Hence for conservation of mulberry outside its natural habitats, a field gene bank has been developed at a Central Sericultural Germplasm Resources Centre, Hosur, Karnataka which maintains *M. austral, M. cathay Ana* Hems, *M. multicaulis* Poir, *M. rotundiloba* Koidz, *M. alba* L., *M. indica* L., *M. teliaefolia* Makino, *M. nigra* L., *M. serrata* Roxb., *M. laevigata* Wall., *M. rubra* L., *M. sinensis* Hort. and *M. bomycis* Koidz. Many cultivars of mulberry have been introduced in India from France, Romania and Japan.

Selection and Hybridization

Until now, selection has only been a method of crop improvement in mulberry for fruits. However, hybridization has been in vogue for mulberry genetic improvement in sericulture, which follows a very specific procedure (Vijayan et al. 2012). Prior to parental selection, the characterization of germplasm accessions is carried out using morphological, biochemical and physiological characters, rooting ability of stem cuttings, leaf yield, leaf moisture, protein and sugar contents, photosynthetic efficiency, physiological water use efficiency etc. Based on a statistical assessment, parents with desired traits are selected and control hybridization is done. Till recently, no variety was developed in mulberry for commercial fruit production. However promising selections of mulberry, intended for commercial fruit production, have been made at ICAR-Central Institute for Arid Horticulture, Bikaner, Rajasthan *viz.*, CIAH Mulberry Selection-1 and CIAH Mulberry Selection-2. CIAH M-1 was found to be earliest with respect to

Mulberry selections 'Thar Lohit' and 'Thar Harit' (CIAH M-2)

maturity period. It took 30-35 days to mature. Recently, CIAH M-1 has been identified as 'Thar Lohit' at the Institute level from ICAR-CIAH, Bikaner. Upon quality assessment, it was found that mulberry genotype Thar Lohit, previously, CIAH M Selection 1 was better than CIAH M- 2 in terms of antioxidant attributes like polyphenol, flavanol, flavonoid and total antioxidant activity. Besides, a new accession of mulberry genotype Delhi Collection has also been shown to be promising in terms of fruit length (5-9 cm), width (1-1.2 cm), weight (4-6 g), attractive colour (reddish to maroon), organoleptic attributes and consumers acceptability.

Soil and climatic conditions

Mulberries like well-drained soil, preferably a deep loam. However, experiments at CIAH had shown that it can be taken up well in sandy soils too. It can be cultivated in sandy soil with proper filling of pits with organic manure and clay soil during planting time. The ideal range of soil pH is 6.2 to 6.8, the optimum being 6.5 to 6.8. Soil amendments may be used to correct the soil to obtain the required pH. Mulberry thrives under various climatic conditions ranging from temperate to tropical located north of the equator between 28° N and 55°N latitude. The ideal range of temperature is from 24 to 28°C. However, Thar Lohit can tolerate temperature ranges from 3 to 48 ^{0}C under arid conditions.

Plant propagation

Budding is the most common method for propagating mulberries. A T-cut is made in the rootstock and a smooth, sloping cut is made on the lower end of the scion. The scion is then inserted into the T and wrapped and sealed. Other types of grafts are also usually successful, although there may be incompatibility between white and black mulberries. The stem cutting is the most common method of propagation in India because of the distinct advantages like speedy multiplication of parent materials and maintenance of the desired characters of the plant. Hardwood, softwood and apical shoot are suitable methods for propagating mulberries. The mature shoots of 6-8 month age with 15-20 cm length, 10-12 mm in diameter, 3-4 healthy buds are selected for cutting. The cut ends of the cuttings should be clean at an angle of 45° with a sharp knife without bark split. Cuttings are potted in sand beds or pots during winter which start sprouting with increase in temperature during February- March which can be shifted to polythene / earthen pots for growth. Irrigation is done regularly afterwards. By the onset of monsoon season saplings are ready for planting in the main field. Semi hard wood cuttings give better result in respect of sprouting and survival. *In situ* budding is also feasible in mulberry under arid and semi arid climate it can be done during March to September months.

Planting and orchard establishment

Mulberries need full sun and also adequate space. The distance between trees should be at least 15 ft. The trees should not be planted near a sidewalk. The fallen fruit will not only stain the walkway, but are likely to be tracked indoors. The trees are quite wind-resistant with some genotypes can be used as windbreaks in the crop production. Pits of 60x60x60 cm can be dug out during summer months in arid regions, where soils are sandy. Well decomposed FYM is mixed with dug out soils and pits are filled. Planting should preferably be done during monsoon. Further, saplings are to be planted in square system. The distance between trees should be 6x6 m.

Training and pruning

No special pruning techniques are needed after the branches have been trained to a sturdy framework, except to remove dead or overcrowded wood. A mulberry tree can be kept to a tidy form by developing a set of main branches, and then pruning laterals to 6 leaves in July in order to develop spurs near the main branches. It is not advisable to prune the trees heavily since the plant is inclined to bleed at the cuts. Cuts of more than two inches in diameter generally do not heal and should be avoided at all cost. The bleeding will be less severe if the tree is pruned while it is dormant.

Manuring and fertilization

Application of a basal dose of organic manure like compost or cattle manure @ 10 tonnes/ ha is necessary for successful establishment of the orchard. Thereafter, the young growing plants should be assisted to put forth vigorous and maximum growth through periodical fertilizer applications. In the case of the rainfed orchard, which is planted in July-August during the South-West monsoon season, the mulberry will receive sufficient rains from the monsoons. This fact should be taken full advantage to achieve maximum growth and build up a huge sturdy frame, so that the plant may stand the following drought months, from January to April very well. This is achieved by applying two doses of nitrogenous fertilizers such as Ammonium Sulphate or Urea at the rate of 25 kg of N/ha for the first application after 2.5 to 3 months of growth and again, another 40 kg of N/ha as the second dose after an interval of another three months. Thereafter, the normal fertilizer application programme could be resorted to i.e. 100 kg N, 50 kg P and 50 kg K per hectare per annum, which may be applied in two equal split doses. The first dose should be applied sometime in late August, i.e. 6-8 weeks after the application of the organic manure and the second dose sometime in late November during the North-East monsoon rains.

Water management

Although mulberry is drought-hardy crop, it needs irrigation during fruiting period. If the roots become too dry during drought, the fruit is likely to drop before it has fully ripened. Irrigation through drip system is recommended for better fruit quality in arid conditions.

Evaluation of mulberry germplasm at ICAR-CIAH, Bikaner

For assessing feasibility of mulberry fruit production in hot arid climate, 15 genotypes were collected from different areas including 02 genotypes from ICAR-NBPGR at ICAR-CIAH, Bikaner. 50 clonal plants each of 03 genotypes *viz*., CIAH Selection 1, 2 and Gurgaon Local were planted in 2007 and evaluated for several morphological and yield parameters. CIAH Mulberry Selection 1 (Purple red colour) & CIAH Mulberry Selection 2 (Greenish white) was found superior to Gurgaon Local (Greenish white). A wide range in term of fruit length (0.9 cm to 9.4 cm) and weight (0.5 gm -7.2 gm) was recorded in different genotypes. The mulberry plants found to tolerate extreme cold and hot temperatures of the arid region. Thus this crop can be viewed one of the sustainable fruit crops of arid region. Very recently, a promising mulberry germplasm MI 572 was evaluated at ICAR-CIAH, Bikaner which was received from CSGRC, Hosur and planted under field condition on July 2013. This genotype came into fruiting during March, 2016,

2017 and also in 2018. Fruit was sweet in taste with slight sourness and reddish in colour. Average yield was recorded 1.51kg per plant. This genotype was found to ripe one week early as compared to variety Thar Lohit. The fruits of genotype MI 572 started for harvesting from 09th March, whereas Thar Lohit started from 23rd of March.

Harvesting and yield

Colour change is the main index of fruit maturity in mulberry. In general, the fruits turn black, red or white, respectively, in *M. nigra*, *M. rubra* and *M. alba* species at the time of maturity and attractive shining on surface and typical aroma. White and red mulberry fruits are ready for harvest during March and April months. The fruits of white mulberries are often harvested by spreading a sheet on the ground and shaking the limbs. Morning time is usually preferred because of more cool and turgid fruit which can be disposed or process during the day Harvesting is done by shaking of individual secondary branches on tree at maturity stage or picking of individual fruits. There is severe damage to fruits if they fall directly on the ground. The mature fruits should be collected and disposed off quickly in local markets because of very short shelf life. Mulberry variety Thar Lohit gives an average yield of 26.5 kg during 8th year of orchard life under rainfed conditions of hot arid ecosystem.

Plant protection

Mulberries are generally free from attack of pests and diseases. Young plants are sometimes damaged by termites particularly during dry period under arid environment. The ripe fruit is very attractive to birds, but there is usually enough fruit left over for harvesting. Termites form an earthen sheath on the stem and feed on the bark. This may result in reduction in leaf yield and drying or killing of plants. Mulching with dry twigs favours the populations build up in endemic areas. More damage is seen in sandy soils of arid zone. For its management, location and destruction of termite colonies by removing queen termite, treatment of mounds with 50 ml chlorpyriphos 20 EC, swabbing or drenching of established plants at the base with 50 ml chlorpyriphos 20 EC are recommended

Several bird species including sparrows, crows, house finches, parrot etc. may cause substantial damage by feeding on ripening fruit. The most effective way is to frighten birds from the orchard. This can be achieved by making noises and use of visual repellents like bird scaring ribbon. Besides, there are some minor pests of mulberry like Bihar hairy caterpillar, mealy bug, thrips, jassids, scale insects, short horned grasshopper *etc*.

Production technology of phalsa, *Grewia subinaequalis*

Phalsa (*Grewia subinaequalis* L.) is one of the oldest indigenous fruits in India, presumably originating from Vadodara, Gujarat. It is widely cultivated in tropical and subtropical India, Pakistan and Bangladesh. In India, it is grown commercially in most of the surrounding areas of cities such as Punjab, Uttar Pradesh, Madhya Pradesh, Haryana, Rajasthan and the Himalayan regions, and is found up to 3,000 feet above sea level. It is also grown on a small scale in Maharashtra, Gujarat, Bihar, Karnataka, Andhra Pradesh and West Bengal. It is drought-tolerant crop of arid and semi-arid regions and also suitable for cultivation in wasteland and salt affected soil. It comes under underutilized fruit crops, but it has valuable fruit that has high nutritional and medicinal properties. Since it is an underutilized fruit crop, it is being cultivated on a very small scale in every state of India. However, it is cultivated commercially near cities.

The health benefits associated with the intake of phalsa fruits are due to the high amounts of phenolic compounds, organic acids, tannins, anthocyanins, and flavonoids present in it. Despite the highly nutritional value of the fruit, its commercial scale cultivation and production did not receive a fair response from the industry. Traditionally, it is cultivated as subsistence farming and hence it is mostly consumed in fresh fruits and juices. In India, ripen fresh fruits consumed fresh in summer, used in preparation of refreshing cool beverage and raw fruits pickled. Being deciduous and responsive to pruning, it is an ideal plant for multi-story cropping. However, its popularity is restricted owing to highly

perishable nature, small size of fruit and non-synchronous maturity, which necessitates repeated harvesting. Therefore, the plantation is mainly confined to the surroundings of big cities. Phalsa production is also possible with the aim of limiting the amount of synthetic chemical nutrients, which have a sustainable and good effect on the soil and the environment. For this reason, organic farming is also possible with excellent quality fruits. At ICAR-Central Arid Horticulture Institute, Beechhwal, Bikaner, experiments are being done to take 100% organic production of phalsa.

Soil and climatic conditions

It is adapted to grow in different types of climatic regions of the tropics and subtropics and to give good yields. It is a crop of hot dry and semi dry regions and very suitable for ecological system. However, the optimal growth areas for phalsa are where a specific summer and winter season can be found. Adequate sunlight and warm temperatures are necessary for fruit ripening, colour development and quality improvement of fruits. Phalsa can be produced in many types of soil, but high quality and good drainage sandy loam soil is good for good growth and development of the plant.

Varietal improvement

There is a wide scope of phalsa production in arid and semi arid climate. But, not much attention was paid to the improvement of it by any research institute and state agricultural universities. Therefore, there is no better variety available in phalsa for commercial cultivation, but during the last 20 years at ICAR-CIAH, Bikaner has collected and stored several genotypes (CIAH – P – 1, P – 1–1, P – 1–2, P – 2, P – 2–1, P – 2–2, P – 2–3, P-3, P-4, P-5, P-6, P-6-1, P-6-2, P-6-3 etc.) in field gene bank and having variation in plant, stem, leaf, flower, fruit size and color etc. from different states of the country, and on which continuous research and evaluation was done for good quality and high production. As a result of several years of continuous study, two varieties have been identified at institute level which is capable of producing high yields in limited resources in hot dry climate."Thar Pragati" is suitable variety for semi-arid and "CIAH-P-1" for arid areas which are being promoted for commercial cultivation.

Plant propagation

Preparation of plants from seeds and cuttings has been standardized for propagation of phalsa. But at the commercial scale, it is being promoted through seeds. July-August is the most suitable time to

Phalsa cultivar 'Thar Pragati'

Phalsa cultivar 'CIAH-P-1'

prepare plants from cuttings. It is very easy to prepare plants from seeds. Seeds should be sown 1.5-2.0 cm deep in poly bags (FYM and soil in equal proportion) in the month of June and irrigate immediately with watering can. Apart from this, watering should be given from time to time as and when required. In this way, about 85-90% germination is obtained from seeds. The plant is ready for transplanting in 5-6 months.

Transplanting

Plants should be transplanted in the field during the monsoon season from July - September. The plant should be well irrigated just after transplanting so that the roots of the plants can be well placed in the soil. Transplanting should be done at a distance 3 x 2 or 3 x 1.5 m. (Row x plant). One to two months before transplanting, pits (60 x 60 x 60 cm size) should be dug in summer and filled with well rotten cow dung manure in the soil. Phalsa plants can also be planted around the field as live fences.

Water management

Phalsa is well adapted to arid and semi-arid climate, so it does not require much irrigation for its successful production. During summer months one to two light irrigations is required so that the plant can tolerate heat. Apart from this, two irrigations should be done at the interval of 15 days after cutting and pruning in December-January, which makes the early sprouting of bushes. After flowering and fruiting and after the fruit is well formed, one to two irrigating should be done during March-April which increases the quality of the fruits.

Training and pruning

Both these processes are very important in the phalsa production. It is trained in such a way that it can take the shape of a bush. Because bush more fruiting branches, resulting the higher the yield per bush. It is pruned once in North India and twice in South India. In order to obtain higher quality yield in hot arid regions, the time and height of pruning of the bushes has been standardized at ICAR-CIAH, Bikaner. The bushes/ plants should be pruned around 15-20 January at a height of 15-20 cm from the ground level. Due to which more new sprouts emerged, the quality of the fruits is also better and yield is also more. In South India, pruning should be done in the months of December and June (twice) for good yield.

Manuring and fertilization

By the way, phalsa production can be obtained without application of manure and fertilizers, but manure and fertilizers should be controlled in order to get quality produce in desert-sandy soils.
To maintain proper humus and fertility in the soil, good rotten cow dung manure or sheep- goat manure should be given every year. After pruning 10 kg (after three years of planting) per bush well rotten cow dung manure should be given which improves sprouting and growth of the plnats. In addition to this, urea, diammonium phosphate and muriate of potash should be given at 100, 50 and 100 gram per plant/ shrub per year respectively, which is given twice at a interval of one month.

Flowering and fruiting

Flowering begins in about two months after pruning and cutting of phalsa and it is completed within 15-20 days. The flowers are yellow in colour and come in bunches. Approximately 90–100 days after pruning, fruit ripening begins from April and lasts till May.

Harvesting and yield

The fruits start ripening in the second fortnight of April and completed in the month of May. The fruits are small, look attractive from red to dark purple, then these are ready for plucking, whose taste is slightly sweet. Fruits are plucked manually and placed in baskets. Its fruits are perishable, so should be consumed within 24 hours of harvesting or sold in the market. Fruit yield per plant from 'Thar Pragati' was

recorded 3.60 kg/ plant during 4th year of planting under rainfed conditions of hot semi-arid ecosystem and 3- 5 kg per bush from selection 'CIAH-P-1' under hot arid condition with limited irrigation water.

Plant protection

Mainly phalsa crop does not affect by diseases and pests in arid region and the damage from them is very less, but sometimes pests cause harm due to pests getting good environment. There are two main pests found on phalsa in this area *i.e.* aphids and caterpillars which cause damage to phalsa. For managing aphid neem oil, neem leaves and neem alkaloid etc. should be sprayed. For effective management of this pest, spray imidacloprid 17.5 SL @ 0.4-0.6 ml / liter or dimethoate 30 EC with 1.5 ml / liter of water. If there is more damage noticed from caterpillar, spray Malathion 50 EC or dimethoate 30 EC with 1.5 ml / liter of water. To control this pest, spray Thar Jaivik 41 EC with 2-3 ml / liter of water.

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