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Article in *Current Horticulture* · January 2020

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Cultivation of underutilized fruit crops in hot semi-arid regions: developments and challenges — a review

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<https://doi.org/10.5958/2455-7560.2020.00003.5>

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Received: January 2018; Revised: March 2019

ABSTRACT

There are quite a large number of indigenous and underutilized fruit crops, which are used by the local inhabitants. In fact, these fruits are the only source of protective food to meet the need of vitamins and minerals of people living in villages. Owing to curative properties, these fruits are used in Ayurvedic and Unani medicines since time immemorial. Apart from their nutritive and medicinal values, a few underutilized fruits have excellent flavour and very attractive colour. Their cultivation is very restricted and they grow mainly as wild. Being tolerant to biotic and abiotic stresses, these fruit crops are suitable for growing in the drought prone areas. Since India has a rich heritage of indigenous fruit types, some of them have already been recommended for commercial planting. It is apparent that there are more fruit crops that await future exploitation. Semi-arid fruits are the oldest fruit tree crops with wide distribution, reflecting their adaptation to a wide range of edapho-climatic conditions of our country. The understanding of various agro-techniques, propagation methods, canopy management, and biotic and abiotic stresses management are equally important for improving their productivity and quality. These crops are known as underutilized but they are locally abundant, and restricted to their geographical location owing to dearth of scientific knowledge. These crops like bael, jamun, tamarind, chironji, khirni custard apple, etc. are immensely constructive and climate smart by surviving in harsh agroclimatic conditions, and can be established on degraded lands, which are presently being underutilized. Therefore, to review the research work done and exploring lacunae in these potential crops critically has become the need of the hour. Hence, research review paper deals all issues and challenges pertaining to these fruit crops.

KEY WORDS: Arid region, Extreme weather, Production potential, Semi-arid fruits, Underutilized fruit crops

The Indian semi-arid regions are characterized by extreme temperature, erratic rainfall, poor soil and water quality, which ultimately limit the productivity of fruit crops. However, these conditions can favourably be utilized to enhance the productivity through advanced fruit technological interventions, resulting in more income by utilizing solar and wind energy, human work force, and developing infrastructural facilities which greatly favour in doubling the income of farmers.

There is a plenty of scope for quantum jump in fruit production in semi-arid areas. The regions have strength to produce high quality bael, lasoda, khirni, karonda, jamun, chironji, tamarind, wood apple, custard apple, fig, phalsa, mulberry, manila tamarind, timru, mahua and palmyra palm (Saroj *et al.* 2018; Singh and Singh, 2012). These fruits are source of income and nutritional security to inhabitants in arid and semi-arid regions (Singh and Singh 2015c, 2015d, 2016a, 2016b and 2016c)

The existing low productivity could be enhanced by following improved new sustainable technologies and inputs with or without irrigation. The amelioration of the extreme conditions is also considered vital for life support to the inhabitants. The recent awareness regarding the potential of these ecologically fragile lands for production of quality produce has not only opened up avenues for providing sustainability in

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livelihood and nutritional security but at the same time for bringing new areas also to increase fruit production. The area expansion and yield potential of semi-arid fruit crops has increased manifold because of development of new varieties and advancement in agro-techniques and processing techniques for development of value-added products.

Demographic status of hot semi-arid fruits

In India, semi-arid zone occupies nearly 37 per cent of the total geographical area (131 million ha) of the total 329 million ha of the country's geographical area, and spread over in Maharashtra (19%), Karnataka (15%), Andhra Pradesh (15%), Rajasthan (13%), Gujarat (9.5%), Tamil Nadu (10%), Uttar Pradesh (7%) and Madhya Pradesh (6%). Semi-arid region is characterized by moisture stress and poor soil and water quality. The annual average rainfall in the semi-arid regions ranges between 290 and 750 mm, which is 2-3 times lesser than potential evapotranspiration. Therefore, fruit crops selected for the region must be tolerant to abiotic stresses and should have reproduction phase synchronized to maximum moisture availability period.

The prevailing stressed conditions necessitate special technologies relating to suitable cultivars, propagation techniques, cultural practices, plant-protection measures and utilization methods to realize maximum value. In semi-arid region, a number of farming communities have small land holdings and poor resources, and cannot afford the burden of credit with available resources, but they can generate income by using scientific rainfed horticultural technologies. Due to erratic rainfall pattern in this region, appropriate technology is needed to increase productivity. With increasing biotic and abiotic pressure, most of the semi-arid regions are confronted with challenges of low productivity due to uncertain supply of water.

Medicinal significance

The nutritional values of most of the underutilized fruits are numerous and they are recommended to be included in use of daily diet. They are widely used in formulations of various ayurvedic medicines owing to rich in minerals, vitamins and phytochemicals. These fruits are rich in flavour and aroma. Beside their importance for nutritional, therapeutical and economic value, diversity of these fruits also has cultural and social value, contributing to the stability of ecosystem. Cultivation and consumption of these crops may be helpful in overcoming the nutritional deficiencies predominant in rural/tribal areas. They also improve socio-economic conditions of poor masses of the country.

In addition to socio-economic and ecological advantage, such fruits have numerous medicinal properties as its different plant parts have pharmacological activities. Therefore, these fruits are rich in minerals, vitamins and phyto-chemicals which need to be harvested for commercialization and utilization of wasteland simultaneously. Biological activities of semi-arid fruits are presented in Table 1.

Morphology, reproductive biology and pollination

At CHES, Godhra, germplasm of bael, jamun, mahua, tamarind, wood apple, custard apple, khirni, karonda, chironji, phalsa and wild noni have been studied for their morphology, flower characters, mode of pollination and pollinating agents. Wide range of variability in leaf morphology, flower characters and phenology has been reported in different germplasm of hot semi-arid fruits under rainfed semi-arid condition (Singh *et al.*, 2013a). Singh *et al.* (2015a) reported intervarietal morphological variability in terms of leaf base margin and apex in bael varieties under rainfed semi-arid conditions. Different pollinating agents (honey bees, beetles, housefly, butterfly, ants *etc*) were found responsible for pollination in different fruit crops. Among them, honey bees were found to be ultimate and legitimate pollinating agents in most of the fruit of semi-arid region.

Morphological, floral, phenological and pollination behaviour in different germplasm of hot semi-arid fruits have been studied in detail, viz. bael (Singh *et al.* 2008, 2011a, 2011b, 2012a 2012b, 2014a, 2019a, 2019e, 2018a and 2018b), jamun (Singh and Singh 2012b, Singh *et al.* 2007a, 2010a, 2011a and 2019d), khirni (Singh and Singh 2005d, Singh *et al.* 2016b and 2019c), tamarind (Singh and Singh 2005b, Singh *et al.* 2006, 2008 and 2010), chironji (Singh *et al.* 2006 and 2010), phalsa (Singh *et al.* 2019a), karonda (Singh *et al.* 2014), custard apple (Vikas *et al.* 2017 and 2018), wood apple (Yadav *et al.* 2018), mahua (Singh *et al.* 2005 and 2008) and wild noni (Singh and Singh 2018, Singh *et al.* 2013b, 2016b and 2014b) under rainfed hot environment of western India. Morphovariations in the form of vivipary, metaxenia and cauliflory in bael germplasm has been reported by Singh *et al.* (2018b) under dryland conditions of western India.

Plant genetic resources

Conservation of genetic resources of underutilized fruits is important, because these species are at the verge of extinction and many are threatened and endangered. The diversity of some of the underutilized fruits is well studied while for other underutilized fruits relatively little has been done yet. Gaps in collection are found between the species and regions.

Table 1. Biological activities of underutilized hot semi-arid fruits

Crop	Biological activities
Bael	Anticancer, sedative, hypnotic, analgesic, anticonvulsive, hypothermic, antimalarial, antipyretic, antidiuretic, antitumor, cardioactive, antihyperglycemic, antidiarrhoeal, anti-inflammatory, antiulcer, antiseptic, antiallergic, antidiarrhoea, astringent, antibacterial, antihelminthic, antispasmodic, antiemetic, cytotoxic anti-diabetic, antidiabetic
Jamun	Antidiabetic, antihyperglycemic, antifungal, anti-inflammatory, neuropsychopharmacological, antimicrobial, antibacterial, radioprotective, gastroprotective, antifertility, anorexigenic, antidiarrheal, ulcerogenic and anti-HIV.
Custard apple	Antiviral, antioxidant activity, respiratory stimulant, antimalarial, antihelminthic, antiulcer hepatoprotective, anti-arthritic, anti-inflammatory and analgesic, anti-HIV, hypoglycemic
Mulberry	Antidiabetes, hypertension, anaemia, and arthritis antioxidant, antimicrobial, and neuro-protective, anti-inflammatory.
Wood apple	Antimutagenic, hypoglycemic and hyperlipidemic vomiting and hiccups, dysentery, indigestion and induce bowel boils and amoebiasis, diuretic activity, anti-bacterial, antifungal.
Tamarind	Cardioprotective, gastric, jaundice, fever,
Khirni	Aphrodisiac, appetizer, arthritis, jaundice, blood purifier
Mahua	anti-inflammatory, hematoprotective, antitumor, analgesic, rheumatism, ulcer, tonsillitis ulcers, dyspepsia, opacity of the cornea, bronchitis, urethrorrhea, leprosy
Chironji	Antidiarrhoea, intercostals, rheumatic pains and skin diseases
Phalsa	Astringent, stomachic, demulcent, rheumatism, antiinflammation, administered in respiratory, cardiac and blood disorders, antimicrobial, anti-platelet, antiemetic, anti-cancer properties anticancer, antioxidant, radioprotective and antihyperglycemic properties
Karonda	astringent, appetizer, antipyretic, antidiabetic scabies, intestinal worms, diarrhoea antipyretic, appetizer, antiscorbutic, antihelminthic
Manila tamarind	Abortifacient, anodyne, astringent, larvicidal, guamachil is a folk remedy for convulsions, dysentery, dyspepsia, earache, leprosy, peptic ulcers, sores, toothache, and venereal disease eczema, sore throat, acne and pimples
Wild noni	Antibacterial, antiviral, antifungal, antitumor, antihelmin, analgesic, hypotensive, anti inflammatory and immune enhancing effects.
Fig	Metabolic, cardiovascular, respiratory, antispasmodic, anti-inflammatory, antidiarrhoea, respiratory haemorrhage, diuretic, diabetics, anthelmintic tuberculosis, anticancer, antidiarrheal
Timru	Antimicrobial, antiparasitic, antidiabetic, antimalaria
Gonda	Antihelminthic, diuretic, demulcent

Source : Maity *et al.* 2009, Singh *et al.* 2019, Sharma *et al.* 2007 Singh *et al.* 2001, Yadav *et al.* 2018, Shyam Sunder 2010, Qureshi *et al.* 2010, Mishra 2018, Hoareau, 1999, Chauhan *et al.* 2012 and Maridass *et al.* 2008.

According to IPGRI (Padulosi, 1999) conservation (both *in-situ* and *ex-situ*) of genetic diversity of underutilized fruits are very poor. This fact indicates that furthermore that the vast bulk of genetic resources of underutilized fruits are in the hands of users and local communities.

In this context, intensive crop specific surveys in target variability pockets and explorations were undertaken in arid and semi-arid regions of diversity rich areas of state, *viz.* Gujarat, Madhya Pradesh, Uttar Pradesh, Chhattishgarh, Haryana, Punjab, etc. and a large number of germplasm of semi-arid fruits were collected over the years for systematic evaluation, characterization and conservation of indigenous germplasm at CHES, Godhra. In past few years, the genetic resource conservation of semi-arid horticultural crops is being maintained in field repository at CIAH, Bikaner, and its regional centre CHES, Godhra, and

CAZRI, Jodhpur. The genetic resource conservation of major semi-arid fruit crops is also maintained in field repository of SAUs and other ICAR Institutes.

Germplasm are being evaluated for development of varieties having desirable traits. Some of the varieties like bael (Goma Yashi), jamun (Goma Priyanka, chironji (Thar priya) and tamarind (Goma Pratek) have been planted on commercial scale at farmers field (Singh *et al.*, 2018c, Singh *et al.*, 2010a). An enormous variability with respect to yield, qualitative and quantitative character in different fruit crops, *viz.* jamun (Singh and Singh, 2005a, 2012b and 2019d), bael (Saroj *et al.*, 2004, 2008, Singh *et al.*, 2015, Sharma *et al.*, 2013, Singh *et al.*, 2014f, 2014g, 2016c, 2019b and 2019e), karonda (Singh *et al.*, 2014), khirni (Singh *et al.*, 2016b), tamarind (Saroj and Awasthi 2004, Sharma *et al.*, 2015, Singh *et al.*, 2006), wood apple (Singh *et al.*, 2016f, Yadav *et al.*,

Table 2. Germplasm conservation of semi-arid fruits at CIAH, Bikaner (Saroj *et al.*, 2018)

Crop	Scientific name	No.	Crop	Scientific name	No.
Bael	<i>Aegle marmelos</i>	21	Manila tamarind	<i>Pythocelobium dulcae</i>	03
Cactus pear	<i>Opuntia ficus-indica</i>	24	Jamun	<i>Syzygium cuminii</i>	2
Phalsa	<i>Grewia subanaequalis</i>	05	lasoda	<i>Cordia myxa</i>	15
Fig	<i>Ficus carica</i>	02	Karonda	<i>Carissa carandus</i>	05
Mulberry	<i>Morus spp.</i>	15	Wood apple	<i>Feronia limonia</i>	03

Table 3. Germplasm conservation of semi-arid fruits at CHES, Godhra

Crop	Scientific name	No.	Crop	Scientific name	No.
Bael	<i>Aegle marmelos</i>	196	Manila tamarind	<i>Pythocelobium dulcae</i>	25
Capecgooseberry	<i>Physalis peruviana</i>	06	Jamun	<i>Syzygium cuminii</i>	68
Phalsa	<i>Grewia subanaequalis</i>	25	Palmyra palm	<i>Borassus flabellifer</i>	2
Badhal	<i>Artocarpus lacucha</i>	04	Karonda	<i>Carissa carandus</i>	40
Mulberry	<i>Morus spp.</i>	15	Fig	<i>Ficus carica</i>	07
Mahua	<i>Bassia latifolia</i>	30	Chironji	<i>Buchanania lanzan</i>	30
Tamarind	<i>Tamarindus indica</i>	25	Wood apple	<i>Feronia limonia</i>	30
Custard apple	<i>Annona squamosa</i>	40	Khirni	<i>Monilkara hexendra</i>	30
Mulberry	<i>Morus spp.</i>	03	Lasoda	<i>Cordia myxa</i>	04

2018), custard apple (Yadav *et al.*, 2017 and 2018), mahua (Bhargava *et al.*, 2017, Dhakar *et al.*, 2015, Singh and Singh 2005c), wild noni (Arya *et al.*, 2014, Patel *et al.*, 2014, Rathod *et al.*, 2016, Singh and Singh 2015e, Singh *et al.*, 2013b), chironji (Singh *et al.*, 2006 and 2016d), phalsa (Singh *et al.*, 2019a and 2019f) and manila tamarind (Awasthi and Saroj 2006) have been reported. At present, ICAR-CIAH (Table 2) and its regional Centre CHES, Godhra are maintaining a large number of diverse germplasm of underutilized semi-arid fruits in field repository (Table 3).

Varietal wealth

The environmental conditions of hot semi-arid regions are very harsh hence; selection of plant species and their varieties for such region for growth and production is important. The crop must have one or another characters like deep root system, summer dormancy, high 'bound water' in tissues, reduced leaf area, sunken stomata, thick cuticle, wax coating of pubescence, presence of latex, and ability to adopt shallow, rocky, gravelly and undulated wasteland. Keeping these facts in view, the importance of underutilized fruits in changing climatic scenario, research work on collection, characterization, evaluation and conservation of underutilized fruits have been initiated at CIAH, Bikaner, and its regional centre CHES, Godhra, and high-yielding quality varieties were developed. Varietal wealth developed is given in Table 4.

Propagation

The importance of underutilized fruits is increasing because people are realising the potential of these fruits. Looking into the importance of these fruits, the demand of their genuine planting material is increasing day-by-day. To meet the demand of planting material, vegetative propagation techniques have been standardized for commercial multiplication. The variability has been observed in plants raised through seeds. Except few plant species, vegetative methods of propagation are used for their multiplication. Propagation through vegetative methods, *viz.* stem cutting, layering, stooling and grafting have been described for many semi-arid fruits. Patel *et al.* (2016) reported that the seed priming treatment improves the germination and vigour of seedling in custard apple. Under dryland condition, *in-situ* establishment of jamun orchard has been found successful with better survival (Singh *et al.*, 2009). Vikas *et al.* (2017) reported that GA₃ and cow urine enhance germination and growth of custard apple seedlings under rainfed semi-arid conditions.

Treatment of seeds with growth regulators (GA₃) enhanced per cent seed germination and growth of seedlings in *Pythocelobium dulce* under hot arid conditions (Singh *et al.*, 2011). In order to optimize the production of semi-arid fruit crops, propagation techniques of jamun, lasoda, khirni, wood apple, manila tamarind, custard apple, mahua, bael, chironji, *etc.* have been standardized for large scale multiplication of plants (Table 5). For better success and survival of

Table 4. Different promising varieties of hot semi-arid fruits

Crop	Varieties	References
Bael	Goma Yashi, Thar Divya, Thar Neelkanth, NB-7, NB-9, NB-5, CISHB-1, CISHB-2, Pant Aparna, Pant Shivani, Pant Sujata and Pant Urvashi	Singh <i>et al.</i> , 2011a, 2012c, 2015a, 2016e, 2019a, Pandey <i>et al.</i> , 2014
Jamun	Goma Priyank, Thar Kranti, Konkan Bahadoli, Jamwant, Paras, Rajamun, Rajendra Jamun-1, Jamwant	Singh and Singh 2012a, Singh <i>et al.</i> , 2010a, 2011, 2016a, 2018b, Mishra <i>et al.</i> , 2014,
Custard apple	Washington PI 98797, Washington PI 107005, British Guinea, Barbados seedling, Island Gem, Bullocks Heart, Pink Mammoth, Balanagar, Mammoth, Red Sitaphal, Yellow Sitaphal, Phule Janki and Sindhan	Hiwale 2015, Vikas 2018, Singh <i>et al.</i> , 2019f
Mulberry	Thar Lohit, Thar Harit, Victoria-1, China White, Saharanpur Local-1, Saharanpur Local-2, S-13, S-34, S-146, S-7999, S-1635, Chak Majra	Saroj <i>et al.</i> , 2018, Singh <i>et al.</i> , 2019f
Karonda	Pant Manohar, Pant Sudarshn, Pant Suverna, Konkan Bold, Thar Kamal	Saroj <i>et al.</i> , 2018, Singh <i>et al.</i> , 2014 and 2019f
Tamarind	Goma Prateek, Prathisthan, PKM-1, T 263, Urigam, Ajanta, Yogeshwari, DTS 1 and DTS 2, Anant Rudhira	Saroj <i>et al.</i> , 2018
Lasoda	Thar Gold, Paras Gonda, Puskar Local, Maru Samridhi	Saroj <i>et al.</i> , 2018, Singh <i>et al.</i> , 2019f
Khirni	Thar Rituraj	Saroj <i>et al.</i> , 2018, Singh <i>et al.</i> , 2015a, 2019c and Singh <i>et al.</i> , 2017
Phalsa	Thar Pragati	Saroj <i>et al.</i> , 2018, Singh <i>et al.</i> , 2018a,
Chironj	Thar Priya	Saroj <i>et al.</i> , 2018, Singh <i>et al.</i> , 2010b,
Mahua	Thar Madhu, NM-2, NM- 4, NM-7, NM- 9	Saroj <i>et al.</i> , 2018, Singh <i>et al.</i> 2016c,
Manila tamarind	PKM (MT) 1	Hiwale 2015, Singh <i>et al.</i> , 2019f
Fig	Poona Fig, Dianna, Dinkar, Conadria, Excel, Chalisgaon	Hiwale 2015, Singh <i>et al.</i> , 2019f
Wood apple	Thar Gaurav	Yadav <i>et al.</i> , 2018, Singh <i>et al.</i> , 2019f

semi-arid fruits, in-situ budding and grafting has been found better with vigorous growth of grafted plants under arid and semi-arid conditions (Singh *et al.*, 2014e). No work on the standardization of rootstocks has been done on such crops till now, which needs attention to assess vegetative compatibility and vigour, fruiting, fruit quality and usefulness to wastelands. Generally, seeds of deshi seedling plants are used as rootstocks for multiplication.

Agro-techniques

Investments are needed in institutional and human capacities to plan and manage water for rainfed horticulture at the catchment scale, where local run off water resources can be diverted, stored, and managed. Under dryland conditions, tapping the potential lies in the availability of an adequate but erratic water resource provided by the rain. The major water-related

challenges for rainfed horticulture in semi-arid regions are less and erratic rainfall, characterized by few rainfall events, high-intensity storms, and high frequency of dry spells and droughts. It is therefore, critical to understand how hydro climatic conditions and water management affecting yields in rainfed horticulture. However, construction of earthen and concrete check dam according to catchment area, development of micro catchment module, full moon and half moon terracing and also with the help of horti-silvi-pastoral system, water loss could be minimized under dryland conditions (Singh *et al.*, 2016d).

Under arid and semi-arid conditions, intercropping during initial years of orchard of bael, chironji, wood apple and jamun had no adverse effects on plant growth up to seven years. However, intercropping in the orchard spaced at 10m × 10m can be done up to 10 years. Intercropping of guar, cucurbits, okra and

Table 5. Commercial methods of propagation of hot semi-arid underutilized fruits

Fruit crops	Time period	Commercial propagation methods	References
Bael	May-June	Soft wood grafting and patch budding	Singh <i>et al.</i> , 2011b, 2014b, 2014e, 2018a, 2019a, 2019c, Singh, 2018,
Chironji	July-August	Soft wood grafting	Singh, 2018, Singh and Singh, 2014a, 2014d, Singh <i>et al.</i> , 2007b, 2010b
Jamun	April -May	Soft wood grafting, patch budding	Singh 2018, Singh and Singh, 2006, 2014b, Singh <i>et al.</i> , 2007c, 2017a, 2011, 2018b,
Lasora	April-May	Patch budding, cleft grafting	Singh, 2018, Singh <i>et al.</i> , 2003 and 2019f
Tamarind	July-August	Soft wood grafting and patch budding	Awasthi <i>et al.</i> , 2005, Singh and Singh, 2007
Mahua	March-April	Soft wood grafting	Singh 2018, Singh and Singh, 2014c, 2015f
Custard apple	April- May	Soft wood grafting	Singh, 2018, Singh and Singh, 2014
Wood apple	April- June	Soft wood grafting and patch budding	Singh, 2018, Singh <i>et al.</i> , 2019f
Karonda	June -July	Seeds and cutting	Singh, 2018, Singh <i>et al.</i> , 2018c
Khirni	April -May	Softwood grafting	Singh, 2018, Singh <i>et al.</i> , 2019c
Phalsa	December-January	Seed and hard wood cutting	Singh, 2018, Singh <i>et al.</i> , 2019f
Manila tamarind	May-June	Patch budding	Singh, 2018, Awasthi and Saroj, 2006
Palmyra Palm	July -August	Seeds and Sucker	Singh, 2018, Singh <i>et al.</i> , 2019f
Mulberry	February-March	Cuttings	Singh, 2018, Singh <i>et al.</i> , 2019f
Wild noni	July- August	Layering	Singh and Singh, 2018, Singh <i>et al.</i> , 2014
Fig	July- February	Cutting, patch budding	Singh, 2018, Hiwale 2015, Singh <i>et al.</i> , 2019f
Palmyra palm	July-September	Seeds	Hiwale, 2015, Singh <i>et al.</i> , 2019f

leguminous vegetable crop increased the income 2-3 times. Cultivation of guar in orchards gave additional advantage of 800 kg seed yield than cowpea. Cover cropping with lobia, moth bean was found to increase water holding capacity of light soils as a result of increased organic carbon content in these regions. Intercropping is economically viable for increasing productivity per unit area and also minimized the risk of crop failure during drought years (Singh *et al.*, 2011a, 2011b, 2019a).

Under dryland conditions, various fruit crop models can be adopted to minimize the risk and enhance the productivity. Bael, aonla and jamun based cropping model are found to be beneficial in term of enhanced yield and income. Bael + aonla + karonda + drumstick, bael+ chironji+ fig+ custard apple, bael+khirni+phalsa +wood apple cropping models are useful to enhance the productivity of dryland tracts of the country (Singh *et al.*, 2019a). Layout and plantation of these crops should be done at closer spacing with proper management of canopy so that productivity and income can be doubled and farmer can generate income throughout the year for better livelihood.

Continuous use of organic mulches are found helpful in improving the soil physico-chemical properties, microbial flora, earthworm population and soil aeration and moisture-holding capacity which ultimately resulted into better growth and yield of plant. Under semi-arid conditions, application of organic mulch (paddy straw, grasses, maize straw *etc.*) in tree basin is beneficial for successful cultivation of fruit crops like bael, jamun, custard apple, wood apple, mahua and chironji. It reduces the loss of moisture from the soil, enhances the rate of rainwater absorption in the soil, and controls the growth of weed.

Mulching can be done with any locally available organic material. Organic mulches reduce the weed population and conserve the moisture in the soil. Mulches should be applied in the tree basin (20 cm thick) after rainy season, and non decomposed organic mulches should be incorporated and mixed with soil of tree basin in the forthcoming monsoon (Singh *et al.*, 2011b). Organic mulches not only improve the soil properties and its moisture holding capacity, also reduce soil temperature (2-8°C) during summer, and increase the yield up to 20-25 per cent under dryland

conditions of semi-arid ecosystem (Singh *et al.*, 2019a).

India is the homeland of many arid and semi-arid drought hardy species of fruit crops like bael, aonla, acid lime, charoli, mahua, *etc.* However, the productivity of all these fruits in India is very low (4-5 t/ha) compared with other major fruit crops grown in India. Many reasons may be attributed to the low productivity, and, to solve this problem, there is a need to develop high-yielding varieties/hybrids that are resistant to biotic and abiotic stresses having dwarf stature and responds to the pruning. By adopting the scientific practices of canopy architecture management and high density planting, yield can be doubled in lesser time and from lesser area.

High-density orcharding results in early bearing, helping to minimize weed problems. High-density planting at a spacing of 5m × 5m in bael, jamun, chironji and mahua has been found useful to double the yield and reduced the problem of harvesting over traditional planting system (Singh *et al.*, 2018d; Singh *et al.*, 2019a). However, crops like phalsa, and karonda can be accommodated at lesser spacing with help of proper training and pruning. By adopting double hedgerow system of planting, the productivity and income per unit area can be enhanced to 2-2.5 times over conventional square system of planting under the rainfed condition. Bael, jamun, chironji and khirni are recommended for planting at 5m × 5m distance under semi-arid conditions to double the productivity (Singh *et al.*, 2019a). Proper canopy architecture of jamun and bael has been standardized (Singh *et al.*, 2017b and Singh *et al.*, 2019a). Singh and Singh (2003) reported that time and level of pruning and application of urea were found helpful in improving the growth, yield and quality of phalsa.

The soils of semi-arid regions in India are poor in organic carbon, nutrients and water holding capacity. Soil depths in these regions are less and nutrient management becomes difficult due the presence of calcium carbonate layer at lower depth. Improved fertilizer management is required to grow crops successfully on such soils. To avoid ammonia volatilization, fertilizers containing ammonium-N or urea should be moved into the root zone with rainfall or irrigation, or be incorporated into the soil. Band placement of P minimizes soil contact thus reducing or delaying the formation of insoluble Ca and Mg phosphates. Crops planted on calcareous soils may require above normal levels of K and Mg fertilizer for satisfactory nutrition. Using tolerant rootstocks and varieties reduces the severity of nutrient related disorders. Deficiency of micronutrients can be corrected through foliar application of chelates. Adequate K supply and organic matter application in the form of cakes, FYM and

organic wastes can improve the availability of microelements. Enriching soil with organic matter is found beneficial for sustainable production of fruits in fragile agro-climatic conditions (Ram and Kumar, 2019)

Most of the minor horticultural crops of semi-arid regions of India are often available only in the local markets and are practically unknown in other parts of the world. Today, consumers are becoming increasingly conscious of the health and nutritional benefits of their food basket. The minor horticultural crops are rich in mineral, vitamins and therapeutic values, and they can serve the purpose as they are growing naturally, therefore, they are free from the toxic chemicals. To achieve this, these fruits need to be popularized in national and international markets. Practically to larger extent, it can be achieved through developing suitable processing and marketing strategies for minor horticultural fruit crops (Meel *et al.*, 2018). In this regard attempts have been made as karonda, bael and aonla based organic products are becoming more popular in the domestic markets. Growing of crops through organics not only hikes the price of produce but also improve soil health.

Post-harvest management

Grading and packaging are the important practices to fetch better price in the market. The packages protect the produce from damage loss as it maintains quality and retains freshness. Corrugated fibre board box (CFB), wood box with suitable cushioning materials are most suitable and economically-viable packing container for transportation of semi-arid horticultural produce. Cushioning material should be physiologically inactive. Moulded pulp tray, honeycomb, cell pack are better than the traditional material like straw and grasses. A large quantity of fruits and vegetables produce goes waste due to unavailability of adequate storage facility in semi-arid dryland areas. Proper storage facility like cool storage, CA and ZECC storage can reduce the post harvest loss to greater extent and can improve the farm income (Singh *et al.*, 2007c 2010a, 2018a, 2019a Singh and Singh, 2012).

The fruits grown in semi-arid regions have been prepared into various processed products by the people utilizing their acquired traditional knowledge like sun drying, pickling *etc.* However, with the application of modern techniques, the quality of products could be improved considerably. The pre-treatment of many fruits with hormone and harmless chemicals results in better quality end products (Meghwal, 2016). Solar drying and electric tray dehydration of fruits and vegetable help to reduce dust load on the product and retain natural colour. Techniques for preparation of different products from underutilized fruits have been

standardized (Mishra, 2018).

Mal nutrition in resource poor areas of semi-arid region is a major problem particularly in women and children. Fruits like tamarind, custard apple, bael, khirni, karonda, phalsa, mulberry, wild noni, wood apple *etc.* are a rich source of vitamins, minerals and dietary fibres. Bael fruits contain higher in riboflavin than many fruits. Fruits like wood apple and custard apple are rich in carbohydrates and minerals which are vital for the maintenance of body and physiological function. These fruits are highly perishable in nature, the marketing of which is a major problem, *e.g.* custard apple gets spoiled within 2-3 days of harvesting, if not consumed (Singh *et al.*, 2007c 2018a, 2019a). Also with the glut in the market, the prices of these fruits drop down drastically making it uneconomical for the farmers to sustain production; the result is that the farmers uproot the trees owing to low price in the market. To avoid the situation, there is a need to extend shelf-life of these fruits and to develop post-harvest

value addition technologies which are simple and adaptable at the farm level.

This will not only result in developing small-scale industry but it will also provide employment to the rural masses throughout the year resulting in increased income of both farmers and workers. Efforts made at the CIAH Bikaner and region research Centre CHES, Godhra were successful and many products, *viz.* dried and dehydrated fruits, RTS, squash, fruit bars, candies, fruit concentrates, powders, wines, and condensed fruit juices through solar drying, were prepared and demonstrated to stakeholders for further commercialization. The tamarind pulp is pressed and preserved in large masses and in dry conditions the pulp remains good for about 1 year. There is tremendous scope for preparing beverages from ripened fruit of chironji. Kernels are being used for the preparation of different kinds of sweets. The products like squash, RTS, and nectar may be prepared from the pulp of the fruits. Value added products of different hot semi-arid fruits are given in Table 6.

Table 6. Semi-arid fruits and their value-added products

Crop	Value-added products
Bael	Preserve, RTS, nectar, ice cream, slab, squash, cider, canned bael slices, pickles and powder
Chironji	Dried kernels, fruit bar
Karonda	Pickle, candy, jelly, jam, preserve, wine, Chutney
Wood apple	Squash, powder, pickle, chutney, jelly, fruit bar
Khirni	Dehydrated fruits, fruit bar, RTS, jam
Jamun	Juice, RTS, squash, syrup, carbonated drink and wine
Phalsa	Juice, squash, syrup
Lasoda	Pickle, culinary
Custard apple	Jam, beverages, ice cream
Tamarind	Tokku (chutney), panipuri masala, juice concentrate, pulp powder, jam, syrup, candy toffee, tamarind karnel powder
Timru	Bidi, dried fruit
Pilu	Squash, dried peelu, wines
Kair	Pickle, dried fruits
Mulberry	Juice, squash and syrup
Mahua	Biscuits, cakes dried powder, seed oil and wine
Manila tamarind	Biscuits, squash and syrup
Aloe	Candy, jelly, pickle, cold cream, crack cream, moisturizer, gel
Fig	Fig paste, concentrate, powder, nuggets, jam

Source: Singh *et al.*, 2016a, 2018a, 2019a, 2019f and Mishra, 2018

CONCLUSION

Keeping in view the agroclimatic conditions of semi-arid region, it is need of hour to create awareness among farmers regarding the various technologies like high-yielding varieties, water harvesting practices, use of organics, IPM, IDM, bio-pesticides, biofertilizers, preparation of value-added products and their marketing can enhance the farm income under prevailing conditions of semi-arid region. Unproductive land can be made productive by selecting the crops having ability to grow under aberrant agroclimatic conditions by proper planning and amalgamation of suitable technologies holistically. As most of the semi-arid fruits cannot be directly used for the table purpose, and thus fetches low prices in the market. Therefore, through processing and value-addition and their efficient marketing, farmer's economic status can be effectively improved with better health and nutritional security. Therefore, focusing attention on such fruit crops is an effective way to help a diverse and healthy diet and to combat malnutrition, so called 'hidden hunger' and other dietary deficiency among the poor rural people and more vulnerable social groups specially tribes of country.

Researchable issues

- Hot semi-arid underutilized fruits are remained neglected. Genetic resources of these crops are still available on farmers' field or in forests which needs to be conserved.
- Research work on underutilized fruit crops should be expanded in order to maximize production and overcome disease and pest problems.