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Fruit crops of Indian semi-arid regions: significance, conservation and utilization strategies—a review

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Abstract

Today, there is a significant demand for nutrient-dense fruits to enhance nutritional and metabolic health in humans. The production of commercial fruit crops is becoming increasingly reliant on inputs-dependent to cope with the losses caused from biotic and abiotic stresses. The region is characterized by severe environmental constraints, making the cultivation of traditional crops unprofitable. Currently, climatic conditions in semi-arid regions are changing, with issues like frost and low temperatures posing challenges for cultivation of many crops. Underutilized semi-arid fruits refer as high nutritional value, medicinal properties, and resilience in adverse soil and climatic conditions; have not received the desired attention.These semi-arid fruits offer numerous advantages, including ease of cultivation, hardiness, and resilience to climate changes, compared to major commercially grown crops. Technologies have been standardized for the large-scale multiplication of quality planting material of semi-arid zone fruits. Moreover, local communities are well-informed about the nutritional and medicinal properties of these crops. However, these lesser- known semi-arid fruits are an essential part of traditional foods, particularly in rural areas and among tribal communities. This review provides an overview of the technologies developed on semi-arid fruit crops that can transform semi-arid ecosystems into horticultural hubs, offering food, nutrition, and livelihood security to the residents.

Key words: Semi-arid, Minor fruit, Biodiversity, Varieties, Production technology.

In semi-arid climates characterized where precipitation is lower than potential evapotranspiration, plants frequently experience water deficits, extreme temperature, poor soil significantly affecting their functioning and productivity (Singh *et al.* 2020). As per FAO classification, regions with a growing period of 75 to 119 days are categorized as semi-arid. In these areas, annual rainfall is half of the potential evapotranspiration. The effects depend on the duration, intensity, and progression rate of the stress, along with the plant's genotype, developmental stage, and interactions with other stress factors (Chaves *et al.* 2016). The high variability of weather in semi-arid climates increases the potential for plant stress. This is likely to be worsened by the rising frequency of extreme events, such as heat waves, driven by climate change. Climate change may impact the adaptability of semi-arid fruit trees, which contribute approximately 48% of global fruit production.

The impact of climate change varies across countries, posing greater food security risks in low-income regions (Medda *et al.* 2022). Climate change is causing an increase in air temperatures, UV radiation levels, and the frequency of extreme events like droughts and floods (Singh *et al.* 2016j). This is particularly detrimental in semi-arid regions, as it can exacerbate the negative effects of salinity, mineral deficiencies or toxicities, and the incidence of diseases and pest infestations in crops. Today, the biggest challenge is to ensure that the growing population has access to stable, safe, and nutritious food.

According to the current Global Hunger Index (GHI), India ranks 111 out of 125 countries, highlighting a dire situation to fight against malnutrition, which ultimately impacts socio-economic development (Meena *et al.* 2022). However, these conditions are crucial to mitigate the impacts of climate change by implementing sustainable land management practices to improve productivity through advanced fruit technology interventions, selection of drought-tolerant rootstocks, cultivar selection and inputs with or without irrigation, increasing income by harnessing solar and wind energy, optimizing human labor, and developing infrastructure that significantly contributes to doubling farmers' earnings (Singh *et al.*, 2020). There is significant potential for a substantial increase in fruit production in semi-arid regions.

These environmental conditions provide an excellent opportunity for cultivating hardy fruit species that are rich in antioxidants and other health-promoting phytochemicals (Krishna *et al.,* 2018; Tiwari *et al.,*2018), while enabling the production of high-quality fruit crops including ber, aonla, bael, pomegranate, tamarind, jamun, chironji, custard apple, wood apple, karonda, lasoda, and fig, as well as vegetables such as cucurbits, legumes, and Solanaceous crops, along with spices, flower crops, medicinal and aromatic plants, can be cultivated in

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semi-arid dryland areas for higher immense nutritional value, economic returns and essential part of the local inhabitants' diet (Saroj *et al.* 2018; Singh *et al.* 2020).

These next-generation crops are yet to be fully popularized and utilized as they currently remain plants of local significance (Singh *et al.* 2022).The expansion in cultivation area and yield potential of semi-arid fruit crops has significantly increased due to the development of new varieties, large-scale production of seeds, fruit basket can provide food, nutrition and livelihood security and quality planting material for dryland fruit crops can significantly enhance the fruit supply along with advancements in agro-techniques and processing methods for creating value-added products to farmers in arid and semi-arid regions, while greatly improving farm income (Singh *et al.* 2018).

Challenges in semi-arid regions

The semi-arid region is further categorized into dry and moist semi-arid zones.In India, the semi-arid zone covers approximately 37% of the country's total geographical area (131 million hectares out of 329 million hectares). This zone is primarily distributed across several states, including Maharashtra (19%), Karnataka (15%), Andhra Pradesh (15%), Rajasthan (13%), Gujarat (9.5%), Tamil Nadu (10%), Uttar Pradesh (7%), and Madhya Pradesh (6%)(Singh *et al.*, 2020). The area receiving annual rainfall ranges between 200-500 mm with a crop growing period of 90-150 days and rainfall two to three times lower than the potential evapotranspiration, are classified as moist semi-arid zones. The soils of these regions are characterized by moisture stress, predominantly light textured, and poor fertility.

Low and unpredictable rainfall, combined with high atmospheric evaporative demand and the soil's poor water retention capacity, restrict the crop growing period to a maximum of 90 days. Consequently, crops chosen for the region must be tolerant to abiotic stress and have their reproductive phase aligned with the period of maximum moisture availability.There is a broad variability in yield, as well as qualitative and quantitative traits, among different semi- arid crops fruit crops, such as bael (Saroj *et al.* 2004; Singh *et al.* 2015; Sharma et al. 2013; Singh *et al.* 2014f; 2014g; 2016; 2019; and Parthasarathy et al., 2021), jamun(Singh and Singh, 2005a, 2012b and 2019d; Singh *et al.*, 2020), tamarind (Singh *et al.* 2006; Sharma *etal.* 2015; Singh *et al.* 2021), khirni (Singh *et al.* 2016b), wood apple (Singh *et al.* 2016f; Yadav *et al.* 2018), mahua (Bhargava *et al.* 2017;Dhakar*et al.* 2015; Singh and Singh 2005c), custard apple (Yadav *et al.* 2017 & 2018).

The existing stress conditions demand specialized technologies, including the use of appropriate cultivars, propagation techniques, cultural practices, plant protection strategies, and utilization methods to achieve optimal value. In the semi-arid region, many farmers have small land holdings and limited resources, making it difficult for them to bear the burden of credit. However, they can generate income by applying scientific dryland horticultural technologies.

Major fruit crops

The region has the capacity to produce high-quality fruit crops, including bael (*Aegle marmelos*),ber (*Ziziphus mauritiana*), aonla (*Emblica officinalis*), tamarind (*Tamarindus indica*), jamun (*Syzygiumcumini*), lasoda (*Cordia dichotoma*), khirni(*Manilkara hexandra*) date palm (*Phoenix dactylifera*), pomegranate (*Punica granatum*), karonda (*Carissa congesta*), mulberry (*Morus* spp.), chironji (*Buchanania lanzan*), wood apple (*Feronia limonia*), custard apple (*Annona squamosa*), phalsa (*Grewia subinaequalis*), fig (*Ficus carica*), acid lime (*Citrus aurantifolia*), manila tamarind (*Pithecellobium dulce*), timru (*Diospyros melanoxylon*), mahua (*Madhuca indica*) and palmyra palm (*Borassus flabellifer*).

Research advances

The research and development journey for arid and semi-arid fruit crops in the tropics and sub-tropics started since 1976 with beginning of an adhoc scheme, which funded research on selected crops through the AP Cess fund of ICAR. Subsequently, this scheme was incorporated into Cell III of the All India Coordinated Fruit Improvement Project (AICFIP) during the 6th Five-Year Plan in 1978. However, during the 7th Five-Year Plan, Cell III of AICFIP was restructured once more to establish the All India Coordinated Research Project on Arid Zone Fruits. Currently, this project operates 18 centres across eleven states in the country, including Rajasthan (4), Maharashtra (4), Gujarat (2), Uttar Pradesh (2), Tamil Nadu (1), Karnataka (1), Andhra Pradesh (1), Punjab (1), Haryana (1), and Madhya Pradesh (1) (Singh *et al.*2022).

The primary objective of the project is to develop appropriate and sustainable technologies for cultivating fruit crops such as ber, aonla, bael, jamun, date palm, fig, pomegranate, custard Apple and tamarind. During the 7th Five-Year Plan, the Planning Commission of India approved the establishment of the National Research Centre on Arid Horticulture (NRCAH) in Bikaner, which was established on April 1, 1993, and was later upgraded to the Central Institute for Arid Horticulture (CIAH) on September 27, 2000.On October 1, 2000, the Central Horticultural Experiment Station, Vejalpur, Panchmahal (Godhra), Gujarat was merged with the CIAH as its Regional Station to focus on semi-arid fruit

crops.However, the research and development of arid and semi-arid fruit crops in India was further propelled by the book "Arid Fruit Culture" (Chundawat, 1990) and Underutilized Fruits of India (Singh *et al.,* 2021), which laid the groundwork for research in minor fruit crops.

Varietal wealth

The hot arid and semi-arid fruit crops particularly in the western part of the country play a vital role in enhancing nutritional and livelihood security in rural and tribal areas, where fruit availability is often limited. In recent years, significant efforts have been undertaken by NARS organizations to develop improved varieties of arid and semi-arid fruit crops.Most of the varieties have been developed through clonal selections of locally adapted genotypes, which have proven to be valuable as they serve as potential sources of stress-related genes and exhibit broader adaptability along with desirable yield and quality traits in arid and semi-arid environments (Table 1).

Propagation technique

The demand for genuine planting material is increasing daily, and to meet this demand, vegetative propagation techniques have been standardized for commercial multiplication.Variability has been reported in plants grown from seeds. With a few exceptions, vegetative propagation methods are used for their multiplication. Techniques such as stem cutting, layering, stooling, and grafting have been standardized for many semi-arid fruit crops. To enhance the success and survival of semi-arid fruits, in-situ budding and grafting have proven to be more effective, resulting in vigorous growth of grafted plants in arid and semi-arid conditions. Details of propagation techniques and period of grafting has been given in Table 2.

Table 1. Improved varieties of semi-arid fruit crops

Crop	Varieties	References
Aegle marmelos	Goma Yashi, Thar Neelkanth, Thar Prakriti, Thar Divya, Thar Gauri, Thar Srishti, Thar Bhavya, Thar Shivangi, NB-7, NB-5, NB-10, NB-8, NB-9,NB-11,NB-17, NB-16, CISHB-2, CISHB-1, CISHB-3, Pant Shivani, Pant Sujata,Pant Aparna, and Pant Urvashi	(Singh *et al.* 2019b; Singh *et al.* 2021a; Singh *et al.* 2014a; Singh *et al.* 2024; Singh *et al.* 2014b; Singh, 2023, Singh *et al.,* 2024a and Singh *et al.,* 2024b)
Emblica officinalis	Goma Aishwarya, NA-5,NA-4, NA-26, NA-7, NA-6, NA-25, NA-10, Laxmi 52, BSR-1, BSR-2,Anand-2and Anand-1	(Singh *et al* 2007; Singh *et al.*2019;Singh*et al.* 2014; Singh *et al.* 2007a)
Ziziphus mauritiana	Gola, Umran, Koma Kirti, Thar Malti, Thar Sevika, Seb and Thar Bhubhraj	(Haldar *et al.* 2019; Saroliya*et al.* 2024)
Syzygium cumini	Thar Kranti, Goma Priyanka, Jamwant,KonkanBahadoli, Paras,Rajendra Jamun-1 andRajamun,	(Singh *et al.*2019; Singh *et al.* 2022)
Annona squamosa	Pink Mammoth,Thar Amrit, Phule Janki, Balanagar, Yellow Sitaphal, Mammoth,NMK Gold, Red Sitaphal, and Sindhan	Yadav *et al.* 2023
Morus spp	Thar Harit,Thar Lohit, Chak Majra,Saharanpur Local-1, Saharanpur Local-2, S-146, S-13, S-1635, S-34 and S-7999	(Krishna *et al.* 2020; Saroliya*et al.* 2020)
Carissa congesta	Pant Sudarshan, Pant Manohar, Konkan Bold, Pant Suverna and Thar Kamal	(Singh *et al.* 2015; Singh *et al.* 2014)
Tamarindus indica	Goma Prateek, Prathisthan,Thar Rashmi,PKM-1, T 263, Ajanta,DTS 1,Yogeshwari, DTS 2and Anant Rudhira	Singh *et al.* 2021; Singh *et al.* 2021a
Cordia myxa	Thar Bold, Puskar Local, Karan Lasoda, Paras Gonda and Maru Samridhi	Meghwal *et al.* 2021
Manilkara hexandra	Thar Rituraj	Singh *et al.* 2019
Grewia subinaequalis	Thar Pragati	(Singh *et al.* 2018; Singh *et al.* 2020)
Buchanania lanzan	Thar Priya	(Singh *et al.* 2016; Singh and Singh, 2016)
Madhuca indica	Thar Madhu, NM-2, NM- 9, NM- 4 and NM-7,	Singh *et al.* 2016
Pithecellobium dulce	PKM (MT) 1	Singh *et al.* 2020
Ficus carica	Poona Fig, Excel,Dianna, Conadria, Dinkar and Chalisgaon	Singh and Singh, 2021
Feronia limonia	Thar Prabha and Thar Gaurav	Yadav *et al.*2023

Source: (Singh *et al.*, 2020; Meena *et al.,* 2022)

Table 2. Propagation techniques of semi-arid fruit crops

Fruit crop	Period of multiplication	Propagation methods	References
Aonla	May-June	Patch budding	(Singh *et al. 2019*; Singh *et al.*2014;Hiwale and Singh 2014; Singh *et.* 2019a; Singh *et al.* 2019c; Singh *et al.*2007)
Bael	May-June	Soft wood grafting and patch budding	(Singh *et al.* 2024; Singh *et al.* 2008; Singh,2023; Singh *et al.* 2011; Singh *et al.* 2018)
Ber	July-August	patch/ shield budding	(Sarolia *et al* 2019; Singh *et al.* 2004)
Chironji	July-August	Soft wood grafting	(Singh and Singh, 2014; Singh *et al.* 2021)
Jamun	April -May	Soft wood grafting, patch budding	(Singh *et al.* 2017; Singh and Singh, 2006; Singh and Singh, 2014)
Lasora	June-July	Seed, Patch budding and micro-propagation	(Meghwal *et al.* 2021; Kumar *et al* 2022)
Tamarind	July-August	Soft wood grafting and patch budding	(Singh and Singh, 2007; Singh and Singh, 2015)
Mahua	March-April	Soft wood grafting	(Singh and Singh, 2015; Singh and Singh, 2005; Singh and Singh, 2016; Singh and Singh, 2014; Singh and Singh,2019;Dhakar *et al.* 2015)
Custard apple	April- May	Soft wood grafting	(Singh and Singh, 2014)
Wood apple	May- June	Soft wood grafting, patch budding	Yadav *et al* 2021
Karonda	June -July	Seeds and cutting	(Singh *et al.* 2018; Singh *et al.* 2014)
Fig	October-November	Cutting	Saroliya *et al.* 2021
Wild noni	July-August	Air layering/seed	(Singh *et al.* 2018; Singh, 2014; Arya *et al.* 2014)
Manila tamarind	May-June	Seed and budding	Singh *et al.* 2020
Khirni	March-April	Softwood grafting	(Singh and Singh, 2015; Singh *et al.*2017; Singh *et al.* 2019)
Timru	May-June	Seed and softwood grafting	Singh *et al* 2022
Phalsa	July -August	Seed and cutting	(Singh *et al.* 2019; Saroliya *et al.* 2020)

Source: (Singh *et al.*2022, 2007b, 2017a & 2018c)

Production technology

Bael

Bael (*Aegle marmelos* Correa), a member of the Rutaceae family, has been widely used in traditional Indian medicine due to its various medicinal properties. In Hindu history, the bael tree is recognized as Vilvam or "Shivadruma," symbolizing the tree of Lord Shiva, and holds a special place of reverence among Hindus. The leaves of *Aegle marmelos* have been used in prayers to Lord Shiva since ancient times. It thrives in different agro-climatic conditions across the country. It shows remarkable resilience and adaptability, even when faced with challenges such as drought, nutrient-deficient soils, and problematic (salty/sodic) soils. Moreover, it exhibits tolerance to certain diseases and pests. Additionally, it successfully adapts to swampy, alkaline or rocky soils with pH levels between 5 and 10. In the *Siddha* system of medicine, the root, flower, leaves, fruit, and bark are use as medicinal substances. The nutritional components present in bael include protein, fat, minerals,fiber, carbohydrates, calcium, phosphate, potassium, iron, and vitamins A, B1, nicotinic acid, riboflavin, and Vitamin C. Varieties such as Goma Yashi, Thar Divya, Thar Neelkanth, Thar Srishti, NB-5, NB-7, NB-9, NB-16, NB-17, Pant Sujata, Pant Aparna, Pant Urvashi, and Pant Shivani are well-suited for semi-arid regions. Budded plants were transplanted during the monsoon season, with proper spacing at intervals of 8m × 8m. Flowering usually starts from March to May and Fruits take approximately 9 to 11 months to ripen on the tree after they set (Singh *et al* 2013). The fruits should be harvested individually, retaining a small portion of the stalk, and must not be allowed to fall to the ground. Grafted plants typically begin bearing fruit in the third year and can yield between 80 to 160 kg per tree per year by the age of 10 years.

Aonla

Aonla (*Emblica officinalis* Gaertn) is also known as Indian gooseberry, is a native fruit of India that belongs

to the Euphorbiaceaefamily. India is the global leader in aonla production, cultivating about 100 thousand hectares with a total yield of 1,197 thousand tonnes. The primary cultivation areas in India include districts in Uttar Pradesh, Karnataka, Bihar, Haryana, Gujarat, Rajasthan, Madhya Pradesh, and West Bengal. It thrives in a wide range of agro-climatic conditions in India, from arid and semi-arid regions to dry and cool arid areas, as well as rainfed zones and regions with varied rainfall patterns.They can tolerate pH levels from acidic to saline/ sodic up to 9.5, an exchangeable sodium percentage (ESP) of up to 35, and electrical conductivity (EC) levels ranging from 6 to 9 ds/m (Pathak, 2003). It thrives on hillsides at elevations of up to 1800 meters above sea level. Mature trees can tolerate extreme temperatures, enduring up to 48°C, but are susceptible to frost in winter, especially in the hot and dry ecosystems of western Rajasthan (Pathak*et al.* 2006).

It contains ascorbic acid, phenolic compounds, along with a moderate amount of carotene, thiamine, riboflavin, carbohydrates, and essential minerals like calcium, iron, phosphorus, and magnesium. Varieties like Goma Aishwarya, NA-6, and NA-7 are recognized for their high yield, larger fruit size, and higher pulp content, making them suitable for commercial cultivation in semi-arid regions. Budded plants were transplanted during the monsoon season, spaced appropriately at intervals of 8m × 8m.Flowering typically starts from February to March in northern and western India, whereas in southern India, it occurs twice, usually in February-March and again in June-July.The fruits are harvested approximately 120 days after flowering. Aonla fruits, an essential element of traditional Indian herbal medicine, are well-known for their significant medicinal and therapeutic properties.

Jamun

Jamun (*Syzygium cuminii* L.) is a member of the Myrtaceae family, with a chromosome number of 2n=40. There are approximately 400 to 500 species. The properties of the species, especially those related to the pulp and seed, have been extensively studied. Jamun possesses numerous valuable properties, and nearly every part of the tree is utilized by both urban and rural communities.A small amount of jamun fruit syrup is effective in treating diarrhea. Vinegar made from juice of slightly unripe fruits has stomachic, carminative, diuretic, cooling, and digestive properties. Volatile oil can also be extracted from jamun fruits. The fruits are used to treat diabetes, heart, and liver issues. Jamun seeds contain jambosin and glycosides, which inhibit the conversion of starch into sugar, and their powdered form is beneficial to maintain diabetes.In India, the majority of jamun trees are found in tropical and subtropical regions, extending to the lower Himalayas up to 1300 meters and the Kumaon hills up to 1600 meters.

The fruit is good source of iron, sugars, minerals, protein, carbohydrate, etc. The flowers are hermaphroditic, light yellow, and grow in the axils of leaves on the branchlets. They have 4 calyx lobes, with the calyx tube not extending beyond the summit of the ovary. The flowers feature 4 white, spreading petals, numerous stamens, and a 2-celled, inferior ovary. Maximum anthesis and dehiscence occurred between 10 am and 12 noon, while the highest stigma receptivity was observed one day after anthesis. Pollination is facilitated by honeybees, houseflies, and wind. Jamun cultivation can expand to semi-arid, resource-poor areas, and wastelands unsuitable for other crops. It tolerates sodic, saline soils, ravines, degraded land, and waterlogged conditions, thriving better in lower salinity and shallow water tables. Jamun can survive in alkali soils with pH up to 10.5 and is suitable for semi-arid subtropical regions with annual rainfall between 350-500 mm.Jamun requires dry weather during flowering and fruit setting.

In subtropical regions, early rainfall benefits fruit ripening and improves size, color, and taste. The jamun varieties Goma Priyanka, Thar Kranti, CISHJ37 and CISHJ42 are suitable for cultivation. The fruit yield ranges from 60 kg per tree for 10-year-old trees to 100-120 kg per tree for trees over 20 years old, with fruit maturity varying from late May and early June. Fully ripe jamun fruits are consumed fresh or processed into beverages like jelly, jam, squash, wine, vinegar, and pickles. The fruit has a sub-acid, spicy flavor, and jamun squash is a refreshing drink perfect for quenching thirst in summer.

Ber

The Indian jujube, or ber (*Ziziphus mauritiana* Lamk.), is an ideal fruit tree for arid and semi-arid regions. Its successful cultivation in the harsh conditions of the Thar Desert in western Rajasthan highlights its remarkable adaptability to desert environments. According to De Candolle (1886) identified Central Asia as the center of origin for ber (*Ziziphus mauritiana* Lamk.), where the species thrives under diverse climatic conditions.It is one of the most nutritious fruits and is often referred to as the “poor man’s apple.” It is one of the richest sources of vitamin C and also good source of minerals, protein and carbohydrates (Gopalan et al. 1985). The popular ber cultivar Gola contains 80–82% moisture, 12.5% carbohydrates, 17–19°Brix TSS, and 0.40–0.70% acidity.The roots, stem bark, and leaves of ber possess medicinal properties.

Locally known as ‘pala,’ the leaves also serve as an

excellent fodder source for sheep and goats.Ber thrives in a wide range of soils, from shallow gravelly soils to deep aridosols. It can tolerate pH levels above 9 and limited soil or water salinity. While ber prefers a drier climate for producing high-quality fruits, it also grows well in tropical and subtropical regions of the country. Known for its drought tolerance, ber trees can withstand extremely high temperatures. However, young plants are highly susceptible to frost during winter, and temperatures below freezing can damage both the fruits and young plants.Budding is the preferred commercial method for vegetative propagation of ber. Various techniques, including T-budding, I-budding, ring budding, patch budding, and forkert budding, have been tested. However, shield or T-budding is the most effective and widely used method.In India, ber is planted during monsoon season using the square system.

The ber varieties and hybridsuch as Goma kirti, Gola, Seb, Umran, Thar Savika, Thar Bhubraj etc are suitable for cultivation under arid and semi-arid conditions. The planting distance is maintained at 6m x 6m in rainfed conditions, while in irrigated orchards, it is increased to 7m x 7m or 8m x 8m.Pruning plays a crucial role in ber cultivation. During the first three years, pruning is carried out to establish a strong framework for the plant. Flowering and fruiting in ber occur on the growth of the current season.Flowering in ber typically begins from July, peaks in September, and continues with sporadic flowers appearing until mid-December.Budded ber plants begin fruiting within a year of planting, while seedling plants take 3-4 years to bear fruit. The yield potential of ber varies depending on agro-climatic conditions, tree age, and variety. A fully grown tree can yield between 30 to 60 tons per hectare, depending on the cultivar and location.The storage life of ber can be extended to 30–40 days when stored at 30°C with 80–90% humidity.

Tamarind

Tamarind (*Tamarindus indica* L.) is a monotypic tree belonging to the Fabaceae family. It originates from the Arabic word "Tamar-E-Hind," which means "Date of India." It is a popular avenue tree, appreciated for its valuable fruits, timber, as well as the shade. Tamarind fruit contains low water content but is rich in proteins, carbohydrates, and minerals. The pulp makes up 30-50% of the ripe fruit (Singh *et al.* 2006), while the shell and fiber comprise 11-30%, and the seeds account for approximately 25-40% (Singh and Singh, 2005b).It is a fruit characterized by low water content and high levels of proteins, carbohydrates, and minerals. The pulp is rich in vitamin C, thiamine, iron, calcium, phosphorus, and dietary fibre, and is enhanced by natural bioactive compounds such as polyphenols and flavonoids, which provide antioxidant and anti-inflammatory properties.

It flourishes in diverse tropical and subtropical regions with hot, dry climates, but it is also well-suited for areas with a monsoonal climate.The Goma Prateek variety has been recognized for its high yield, larger fruit size, and greater pulp content, making it recommended for commercial cultivation in semi-arid regions (Singh *et al.* 2013).Tamarind plants were grown from seed, both in situ and in a nursery, where patch budding was performed and transplanted at spacing 8m x 8m. The leaves are typically evergreen but may drop temporarily in extremely dry regions during the hot season. The inflorescence racemes are small, measuring 5-10 cm in length, and are terminal and lateral, often drooping and accompanied by panicles. The nectar-producing flowers attract honeybees to gather nectar and pollen, likely aiding in cross-pollination. Flower bud development occurs 20 days after the first visible initiation. The fruit yield ranged from 40-50 kg per tree for those aged 6-7 years to 150-200 kg per tree for trees over 20 years old, with fruit maturity differing among trees from early March to late May. Tamarind is high valuable fruits for its pulp, which serve various domestic and industrial purposes.

Custard apple

Custard apple (*Annona squamosa* L.) is a deciduous or semi-deciduous tall woody shrub, reaching a height of about 5-6 meters, with irregularly spreading branches. Belonging to the Annonaceae family, it is native to the tropical regions of the West Indies (Porwal *et al.* 2011). Known by various vernacular names such as sugar apple, sitaphal, sweet sop, and sharifa in the Indian subcontinent, it is a highly nutritious crop. Custard apple is rich in essential minerals like calcium, potassium, and phosphorus, as well as calories, vitamin C, and carbohydrates. In India, it is cultivated in regions including Assam, Bihar, Madhya Pradesh, Maharashtra, Odisha, Rajasthan, Uttar Pradesh, Andhra Pradesh, Telangana, and Tamil Nadu.

Custard apple is resilient to hot and drought conditions, but high atmospheric humidity is essential during flowering to enhance fruit set. However, continuous rainfall during fruit set is undesirable. The tree is sensitive to frost and prolonged cold periods. From December to February, it enters dormancy and sheds its leaves. The plant can thrive in a wide range of temperatures, from 10°C to 45°C. Custard apple trees grow well in light and medium-textured soils, such as sandy loams, loams, rocky or gravelly sandy soils, and clay loams. The tree tolerates moderately acidic to neutral soils, with a pH range of 5.5 to 8.5. Thar Amrit, Arka Sahan, Balanagar, and Mammoth are

recommended cultivars for semi-arid climatic conditions. Budding and softwood grafting are successful methods of propagation for custard apple.

The best results for these methods are achieved during the months of March-April.Custard apple should be planted at a spacing of 5m x 5m (400 plants/ha). However, for high-density planting, a spacing of 6m x 3m (540 plants/ha) is considered ideal. Its seedling plants begin bearing fruit after three years of planting, whereas grafted and budded plants start flowering in the second year. Typically, custard apple plants take five or more years to develop a full canopy and achieve economic yield. Fruit yield can vary significantly from tree to tree. On average, a 7-year-old tree produces 100-150 fruits, with a total yield of around 7 tons per hectare.

Wood apple

Wood Apple (*Feronia limonia* Swingle), also known by vernacular names such as kaitha, kainth, bel, katha phal, kothbel, and monkey fruit, is an underutilized dryland fruit crop belonging to the Rutaceae family.The wood apple is native to South India and Sri Lanka. In India, it is commonly found in the forested areas of arid and semi-arid regions, including Maharashtra, Andhra Pradesh, Tamil Nadu, Kerala, Karnataka, Madhya Pradesh, and the western Himalayas. Known for its medicinal properties, the wood apple is valued for its astringent qualities and its beneficial effects on the cardiovascular system. Its fruits and leaves are used to treat conditions such as vomiting, hiccups, dysentery, indigestion, and to promote bowel movements in children. The fruits are considered toning, refreshing, astringent, beneficial for the heart, and anti-scorbutic (Shyam Sunder, 2010).The nutritional composition of wood apple seeds per 100 grams of ripe edible pulp includes 4.0% moisture, 26.18% protein, 27% fat, 35.49% carbohydrates, 5.03% ash, 1.58% calcium, 1.43% phosphorus, 0.03% iron, and 0.08% tannins.

Wood apple is commercially propagated through seed, softwood grafting, or patch budding, both in the field and nursery conditions, typically during March-April. In situ softwood grafting in wood apple achieves over 80% success under the semi-arid conditions of Gujarat (Hiwale, 2015).Pits measuring 90 cm x 90 cm x 90 cm are dug during the summer months. Well-decomposed organic matter is mixed with the soil before planting. Planting is done during the monsoon, and the plants should be irrigated immediately after planting. To ensure high productivity, they should be spaced 8m x 6m apart. Initial plant growth is slow in arid regions.

Thar Prabha and Thar Gourav are suitable variety of wood apple for arid and semi-arid conditions.Wood apple plants should be trained by removing crossing branches during the initial growth stages, as grafted plants are prone to lanky and uneven growth habits.The fruit begins to mature in October and continues until January in various parts of the country. In arid and semi-arid conditions, fruit maturation starts in September and finishes by December. The fruit yield per plant varies between 70.0 and 120.0 kg in the 10th year of planting under rainfed conditions in semi-arid ecosystems.

Karonda

Karonda, scientifically known as *Carissa carandas* L, is a member of Apocynaceae family. It is an indigenous shrub,hardy, multipurpose shrub native to dry regions and can be grown in any type of soil in both tropical and subtropical climate regions of the Himalayas, as well as in Maharashtra, Madhya Pradesh, Rajasthan, Uttar Pradesh, Bihar, and West Bengal.Important species of *Carissa* include *Carissa grandiflora, Carissa bispinosa, Carissa edulis, Carissa ovata* and *Carissa spinarum*.The cultivars are categorized based on fruit color such as green, pink, and white. Karonda fruits are small, rounded, succulent, and fleshy, with a juicy pulp. Known for their bitter-sour and acidic taste, they are widely used in Indian cuisine. Mature fruits are commonly.

The fruits are consumed fresh but are more commonly used for processed into high-quality pickling, candies, making chutneys, and other culinary purposes. The fruits are highly nutritious, providing 1.1% protein, 2.9% carbohydrates, 1.5% fiber,2.9% fat, 0.6% minerals, and 42 kcal of energy per 100 g of the edible portion.It is a subtropical plant, sensitive to cold, and susceptible to damage in frost conditions. Itcommercially propagated through seeds but it can also be propagated using hardwood cuttings. Fresh seeds should be used for raising seedlings, as they typically lose viability within 4-5 weeks. Seedlings are grown in polythene bags during the rainy season and can be transplanted in main field after one year at a spacing of 4m x 4m.Thar Kamal variety of Karonda is the most suitable variety for a semi-arid ecosystem.Plants begin flowering in the third year, with the peak flowering period occurring in March. The fruits ripen in the month of June and continue up to September, and the fruit yield reaches 13.00 kg per plant by the ninth year under rainfed conditions in a hot semi-arid ecosystem.

Chironji

Chironji, or Charoli (*Buchanania lanzan* Spreng.), is an outstanding tree for agroforestry and social forestry systems. In wasteland development and dryland horticulture, it holds great importance due to its diverse uses and ability to withstand harsh climatic conditions. The kernel is highly nutritious, rich in protein, and

produces sweet oil that can serve as a substitute for olive and almond oil. It contains 33.50% oil, with 1.90% being unsaponifiable (Singh *et al.* 2006).The total lipid content extracted from chironji kernels was 65.60% of the dry kernel, comprising 90.40% neutral lipids, 3.4% glycolipids, and 6.2% phospholipids (Singh *et al.*2020e).

Chironji is a very hardy plant that thrives in rocky, gravelly red soils, as well as saline and sodic soils. However, despite its resilience, the plants do not survive in waterlogged conditions. Trees are cultivated in degraded rocky areas, including salt-affected soils. However, for optimal growth and productivity, well-drained deep loam soil is ideal. 'Thar Priya' variety recommended for commercial use in the semi-arid and dryland areas. It can be easily propagated using softwood grafting. It is a highly heterozygous, cross-pollinated crop, resulting in seedlings that display a wide range of variations. Flowering begins in January-February on well-developed panicles that bear hermaphrodite and pseudo-hermaphrodite flowers and the fruit is a drupe. Fruits are ready for harvest in April and May. The kernel can be used to prepare sweets and also yields high-quality timber for various uses.

Khirni

Khirni (*Manilkara hexandra*Roxb.) is an important fruit tree that can be successfully cultivated in the wastelands and degraded lands of tropical and subtropical India. It is commonly referred to as 'Khirni' and 'Rayan' by tribal communities in various states of India. The fruits of Khirni hold significant economic value, as mature fresh fruits are sweet and provide a rich source of iron, minerals, sugars, protein, carbohydrates, and vitamin A (Singh *et al.* 2020). The tree is medium-sized, evergreen, and has a spreading growth habit. It is commercially utilized as a drought-resistant rootstock for sapota in various regions of the country. The plant can withstand drought conditions for a period and also tolerate heavy rainfall. Its cultivation can be expanded to arid and semi-arid regions, resource-poor areas, and wastelands where other crops cannot be successfully grown. 'Thar Rituraj' has been developed and is considered highly suitable for dryland conditions (Singh *et al.* 2015d). Its bark and fruits are utilized for various medicinal purposes, including the treatment of ulcers, dyspepsia, bronchitis, leprosy, and more. The seeds contain approximately 25% rayon oil, which is used for cooking and possesses medicinal properties. The bark contains 10% tannin, which is used to treat fever and can also be employed in tanning processes.

Phalsa

Phalsa (*Grewia subinaequalis*), a member of the Tiliaceae family, is one of the oldest fruits known in India. Ripe phalsa fruits are purple when mature and may turn black as they fully ripen on the bushes. These mildly acidic fruits are rich in vitamins A and C, as well as minerals. In Ayurveda, the ancient Indian medical treatise, phalsa fruits are considered a cooling tonic and an aphrodisiac. The mucilaginous extract from the bark is used in sugar clarification, and the fiber from phalsa is utilized for making ropes. It can thrive in neglected and water-scarce conditions where only a few other crops can survive. Additionally, it serves as an important catch crop in commercial orcharding. Phalsa is a tall shrub characterized by rough bark on its stem and numerous long, slender, drooping branches, with the young branchlets densely covered in hair. Freshly extracted seeds should be used for raising seedlings.

Consequently, several local varieties of phalsa have been reported in certain parts of the country, including Local and Sharbati. 'Thar Pragati' a high yielding has been developed for cultivation in semi-arid dry areas. The fruits start to ripen 40-45 days after flowering. In southern India, phalsa fruits begin to ripen during the hot summer months of March and April, while in northern India, they ripen by the end of May. Fruits are hand-picked individually and collected in baskets made of bamboo or pigeon pea plants, lined with polythene sheets or newspaper cuttings for cushioning.Fruits harvested at the red ripe stage can only be stored for a day, so they are promptly marketed in local markets.

Mahua

Mahua (*Bassia latifolia*), the Indian butter tree, is a socio-economically significant multipurpose tree widely grown in the plains and forests of central and northern India. Its flowers, fruits, and oil are utilized in various ways. The corolla, commonly known as mahua flowers, is a rich source of sugar and contains significant amounts of vitamins and minerals. Mahua is a very hardy plant that thrives in rocky, gravelly red soils, as well as saline and sodic soils Thar Madhu, NM-2, NM-4, NM-7, and NM-9 are high-yielding varieties developed for commercialization in semi-arid dry regions. Plants are transplanted during monsoon season at spacing 8m × 8m.Every part of the Mahua tree produces valuable economic products, making it a highly beneficial resource for tribal and impoverished communities in India.

Fruits can be consumed raw or cooked, while the pulp serves as a sugar source for alcoholic fermentation. The seeds are a rich source of oil. The oil extracted from the kernel is used for culinary purposes and is approved for the production of vegetable oil. The leaves are used to make plates for various purposes.Mahua seeds can also be processed into defatted flour, which has significant

potential for use in bakery products. The saponin extracted from the seeds has industrial and commercial applications. The oil cake left after extraction serves as manure and has insecticidal properties. Additionally, the tree provides high-quality timber for various uses.

Fig

Fig (*Ficus carica* L.) is among the oldest cultivated fruit species in the world.It belongs to the Moraceae family, which includes over 1,400 species across approximately 60 genera.It has been an essential source of nutrition and health across various civilizations since ancient times, and its value continues to endure today. It spread to distant regions of the world, including China, India, Ethiopia, Arabia, Australia, and the Americas. The fig tree's remarkable adaptability to a wide range of soils, especially its tolerance to water scarcity and semi-tolerance to salinity, has made it increasingly important for cultivation in dry and semi-arid areas. It thrives in regions with an average annual temperature of 18-20°C, mild winters, and hot, dry summers (35-37°C).

A dry climate with optimal temperatures during fruit development and maturation yields the best quality figs. Fig fruit is highly nutritious, rich in dietary fiber, iron, calcium, protein, and calories. Dried figs also contain polyphenols, including anthocyanins and flavonoids, along with protein, fiber, carbohydrates, and essential minerals such as calcium, phosphorus, and iron.Fig can be cultivated in a variety of soil types, but deep clay-loams are the most suitable. Well-drained alluvial clay loams or medium black soils are also ideal for fig cultivation. Poona is one of the most commercially significant fig varieties. Rooting hardwood cuttings is the common propagation method for figs. The best rooting results are achieved with cuttings from 3-year-old wood, measuring 30-40 cm in length and 1.5 cm in diameter.

Additionally, figs can be propagated through air layering, shield or patch budding, and side grafting.The planting season varies by region: in South India, it is from August to September; in Western India, from June to July; and in North India, from January to February. Fresh figs are highly perishable, so slightly immature fruits should be harvested for transportation to distant markets. The harvesting season typically runs from mid-February to June, with yields ranging from 180 to 360 fruits per tree.

Manila tamarind

Manila tamarind (*Pithecellobium dulce* Roxb.) is commonly known as Madras thorn Monkey pod and *Jungle jalebi* and belongs to the *Fabaceae* family. It is a multipurpose, fast-growing, medium-sized thorny tree used as live fencing, animal fodder, hardwood timber, windbreak and a potential source of lac culture. Its fruit has a sweet acidic taste and high content of dietary fiber, proteins, Ca, Fe, P, unsaturated fatty acids and antioxidants. Manila fruit is used to treat toothaches, mouth ulcers, sore gums, dysentery, chronic diarrhea, stress, aging symptoms and dark skin spots.

Timroo

Timroo (*Diospyros melanoxylon* Roxb.) or tendu belongs to the family Ebenaceae and is native to India and Sri Lanka. It is found in endemic conditions within limited areas of Gujarat, Madhya Pradesh, Rajasthan, Jharkhand, Bihar, Chhattisgarh and Tamil Nadu. It is a long-lived, deciduous, dioecious, seedless parthenocarpic berry fruit. Its leaves are commercially used for bidis making (indigenous, traditional cigarette), agricultural implements and furniture. Most importantly, it is used as an indicator for high sulfur dioxide concentration. Timroo fresh fruit has high total phenolic content, flavonoids, scavenging activity, antioxidants and β-carotene content as equal or more to guava, plum, star fruit, mango, kiwi and apple fruit. Its bark extracts are used to treat dyspepsia, diarrhoea, and smallpox (burnt bark) by ethno medicine practitioners.

Palmyra palm

Palmyra palm (*Borassus flabellifer* L.) is a member of family Arecaceae and is native to tropical Africa and distributed from India across Southeast Asia to New Guinea. In India, it is found growing naturally across the country. It is a monocotyledonous and dioecious plant. Since ancient times, plants and trees have played a crucial role in enhancing human well-being. Various parts of plants and trees, including roots, stems, leaves, flowers, and seeds are utilized as medicines to treat a wide range of diseases. The young roots of the tree are used as a diuretic and anti-parasitic remedy and a decoction made from these roots is employed to treat respiratory and gastritis related disorders (Prasad *et al.* 2023).It is an underutilized palm that grows naturally in forests and barren lands. It is a large tree that can grow up to 30 m in height, with the trunk having a base circumference of 1.7 m.

Limited research has been conducted on the variety development of the Palmyra palm. Most planting is carried out using location-specific elite palms, primarily SVPR-1. It produces 298 liters of padaneer/tree annually, with a higher jaggery recovery rate of 144 g of jaggery per liter of padaneer. Local fruits are categorized as black-skinned and red-skinned palms. Black-skinned fruits have less red pigment, while red-skinned fruits exhibit varying black pigments with a high red pigment distribution.

High- Density Planting

The optimal plant density of orchard largely depends on factors such as the plant type, soil fertility, tree varieties, growth habits, rootstock selection, and management practices. According to various planting systems such as square, rectangular, triangular, quincunx, hexagonal, contour, and hedgerow methods can be selected for planting. In the plains, planting is typically carried out using the square or rectangular system, whereas on sloping lands, fruit trees are planted on contour terraces, half-moon terraces, trenches, bunds, or within micro-catchments. In a micro-catchment, which can be triangular or rectangular, trees are planted at the lowest point where runoff collects.The planting distance for Aonla (8 x 8 m), bael (8 x 8 m), jamun (8 x 8 m), mahua (8 x 8 m), ber (6 x 6 m), phalsa (2 m x 2 m) and karonda (4x4 m) cultivation is optimum.

The main reason for low productivity can be attributed to many factors, emphasizing the need to develop high-yielding varieties or hybrids that are resistant to biotic and abiotic stresses, have a dwarf stature, and respond effectively to pruning. High-density planting combined with effective canopy management can double the yield in less time and from a smaller area. Additionally, high-density orcharding promotes early bearing and helps reduce weed problems. High-density planting is adopting at a space of 5×5 m in bael, aonla, jamun, chironji, and mahua has proven effective in doubling yield and reducing harvesting challenges compared to traditional planting systems.

Moisture conservation and mulching

In arid and semi-arid ecosystems, where water is a major problem, the primary motive is to conserve available soil and rainwater. Harvesting, rainwater can provide sufficient water to enhance plant establishment and increase crop yields. Effective moisture conservation practices include the use of various mulching materials such as paddy straw, Husk, Maize straw, grasses etc, were applied to a thickness of 20 cm after the rainy season, which help increase soil moisture and water retention during intermittent rainfall or irrigation. Mulching helps to regulate soil temperature and moisture, suppress weed competition, and improve soil structure and biological activity, ultimately boosting crop yields. Furthermore, using organic materials as mulch also can impart manifold beneficial effect on earthworm and microbial population, soil fertility and growth and yield (20-25%) of plant under semi-arid ecosystem. Paddy straw mulch has been found effective in improving both the production and quality of aonla, including TSS, Vitamin C, and total sugar, under the semi-arid conditions of Gujarat (Singh *et al.* 2019).

Organic nutrient management

Soils in semi-arid regions are low in organic matter, which affects nutrient use efficiency and reduces soil's ability to retain moisture. Soils in semi-arid regions are often low in nutrients. Fruit plants are nutrient-demanding crops that deplete soil fertility significantly, highlighting the need for the judicious application of fertilizers. Providing balanced nutrition to fruit plants at the right time, based on their age, is essential for optimal growth and productivity. Organic fertilization enhances fruit crop tolerance to soil stresses such as drought, salinity, alkalinity, and toxic elements. Many studies have shown that applying organic manure improves soil's water and nutrient use efficiency by increasing organic matter and enhancing its physical, chemical, and biological properties. This promotes better plant growth and helps mitigate adverse conditions in the rhizosphere. Vermicompost is widely used in fruit crops due to the growing interest in organic farming. It is a rich source of micro and macronutrients, vitamins, growth hormones, and enzymes. Its application, along with FYM, significantly increases organic content and reduces bulk density.

Post- harvest management

Grading and packaging are essential practices for securing higher prices in the market. The packaging protects the produce from damage and loss by preserving its quality and maintaining its freshness. Corrugated fiberboard/boxes (CFB) and wooden boxes with appropriate cushioning materials are the most suitable and cost-effective packaging containers for transporting semi-arid horticultural produce. Proper storage facilities, such as cool storage, controlled atmosphere (CA) storage, and Zero Energy Cool Chambers (ZECC), can significantly reduce post-harvest losses and enhance farm income (Singh *et al.* 2018a, 2010a).

Fruits grown in semi-arid regions have been processed into various products using traditional knowledge, such as sun drying and pickling. However, the application of modern techniques can significantly enhance the quality of these products. Pre-treating many fruits with hormones and safe chemicals leads to higher quality end products. Solar drying and electric tray dehydration of fruits and vegetables help reduce dust contamination and preserve their natural colour. Techniques for producing various products from underutilized fruits have been standardized (Reddy *et al.* 2018).

Malnutrition is a significant issue in resource-poor areas of semi-arid regions, particularly affecting women and children. Fruits such as bael, ber, tamarind, mulberry, custard apple, karonda, khirni, mahua, phalsa, chironji, fig, wild noni, and wood apple are rich in vitamins, minerals, and dietary fiber. Bael (*Aegle marmelos*) is a rich source of bioactive compounds, which have been shown to be effective against several major ailments. It is also an important component in various traditional formulations for treating different diseases (Singh *et al.*, 2020, 2021). Wood apple also offers antioxidant, anticancer, antidiabetic, antimicrobial, and hepatoprotective benefits. Wood apple also containing contains a diverse array of bioactive compounds, including phenols, flavonoids, alkaloids, terpenoids, tannins, saponins, fatty acids, steroids, glycosides, gum mucilage, and fixed oils. Both the leaves and fruits of ber are significant from a nutritional perspective due to their high mineral content, vitamin C, and other essential nutrients (Saroliya *et al.* 2024).

Additionally, with an oversupply in the market, the prices of these fruits plummet, making it uneconomical for farmers to continue production. As a result, many farmers uproot their trees due to the low market prices. To prevent this situation, it is essential to extend the shelf life of these fruits and to develop simple, adaptable post-harvest value addition technologies at the farm level. This will not only foster the development of small-scale industries but also create year-round employment for the rural population, leading to increased income for both farmers and workers. The efforts undertaken at the CIAH Bikaner and the Regional Research Centre CHES in Godhra were successful, resulting in the development of various products, such as dried and dehydrated fruits, ready-to-serve (RTS) beverages, squash, fruit bars, candies, fruit concentrates, powders, wines, and condensed fruit juices through solar drying. These products were prepared and demonstrated to stakeholders for further commercialization. Products such as squash, ready-to-serve (RTS) beverages, and nectar can be made from fruit pulp(Table 3).

CONCLUSION

Considering the agro-climatic environment 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 agro-climatic 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

Table 3: Value-added products of semi-arid fruits

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

Hiwale, 2015, Singh *et al.* 2019, Yadav *et al.* 2018a & 2018b

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.

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