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Present status and future prospects of Ber (*Ziziphus mauritiana* Lamk.)-A review

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ABSTRACT

Ber (*Ziziphus mauritiana* Lamk.) is one of the hardy fruits that can be profitably cultivated in arid and semi-arid conditions, where most other fruit trees fail to grow due to lack of irrigation and other environmental constraints. It is mainly cultivated for its fresh fruits and rightly called as poor man's apple due to its high nutritional value *i.e.* higher protein (0.8 g), β-carotene (70 IU), vitamin C (50-100 mg) and medicinal value. In North India, ber flowers in the month of August-September. It mainly produces heavy flowers in the auxiliary cymes on maturation, and current season's growth with very high fruit set percentage. It can be processed to prepare various value added products *i.e.* murabba, pulps, jam, candies and beverage. The best method of commercial propagation is by budding and the widely adopted is shield budding (T or I budding). Recently success in micro propagation of ber has also been achieved and the best explant for *in vitro* micro propagation is stem from mature tree. Due to its ability to withstand adverse climatic conditions, it is truly a "desert apple" or "king of arid fruits" and can be profitable grown by farmers of arid and semi-arid regions of India.

Introduction

The ber (*Zizyphus mauritiana*) belonging to the buckthorn family Rhamnaceae and is also called as jujube (Singh *et al.*, 2007). It is mostly grown in semi-arid regions of tropical and sub-tropical parts of India. It is the only fruit tree which is profitably grown by Indian farmers under dry land conditions. Apart from India it is mainly also grown in some countries of central Asia *i.e.* China and Taiwan. The fruit has religious association with Indian culture since ancient times. The fruit tree is hardy and adapts and thrives well in areas with poor water availability, inferior soil and adverse climatic conditions (Krishna *et al.*, 2014). It is believed to have originated in India and is regarded as the king of arid fruits; it has also earning the title of poor man's apple due to its high nutritive value. Ber is a seasonal fruit which can be made available throughout the year with different food products with extended shelf life. The tree suits well in areas with poor soil fertility and management where most other fruit trees fail to establish them or significant yield losses occurs (Dalal *et al.*, 2019). In India three main species are found and among

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them *Z. mauritiana* is mainly grown and has high economic importance with several varieties been released in the country. India is the largest producer of ber. It is found growing wild, semi wild and also in cultivated in almost all parts of the country. The area under cultivation in India is 8.7 lakh ha with an annual production of 8.9 lakh tones (Bolada *et al.*, 2012). Indian Ber (jujube) have varieties known for their taste, nutrition and higher yields. The varieties like Umran, Karaka, Gola, Seb, Chhuhara, Sanaur-2, Ilaichi and Mehrun are the most promising varieties of ber in India (Azam-Ali *et al.*, 2001). Fruits are mostly seasonal and are highly perishable. It is estimated that the total spoilage of fruits in India due to post-harvest losses is around 20- 30 % (Madan and Ullasa, 1993). Lack of adequate processing facilities, transportation and storage are the main bottleneck leading to loss of valuable produce. The quality of fruit is best under hot, sunny and dry conditions, but for optimum growth and flowering and maturity there should be availability of moisture in the soil. Ber is known for its ability to withstand adverse climatic conditions and shows a good level of resistance against salinity, drought and water logging. The tree frequently faces desiccation damage due to high rate of cuticular transpiration, which usually associated with high fatty acids and low aldehydes and alcohol content in the waxy cuticle (Dalal *et al.*, 2019). The major growing states in India are Madhya Pradesh, Bihar, Uttar Pradesh, Punjab, Haryana, Rajasthan, Gujarat, Maharashtra and Andhra Pradesh. The area under ber has increased from 42,000 Ha to 49,000 Ha from 2014-15 to 2016-17 resulting in an increase in production from 401,000 MT to 481,000 MT during the same time period. The present work thus focuses on the importance of ber and as an important means to increase farmer's income of the in rainfed/dry land conditions.

Botanic description

The Indian ber is an evergreen shrub or tree with a spreading canopy and vine-like branches, the leaves have and dark green appearance on the upper surface with fine tooth at margin (Pareek *et al.*, 2007). The height of the tree may reach up to 15 m high, with a trunk diameter of 40 cm or more. It bears stipular spines and many drooping branches. The tree has a well-developed tap root system which helps in its establishment. It flowers in autumn, bears fruits at the end of winter. It sheds leaves during hot weather after fruiting and does not withstand cold conditions. The inflorescence is cymose with 15-28 flowers per cyme (Singh and Sharma, 2020). The tree bears are pale white pentamarous flowers with stamens attached to petals. At the time of anthesis the stigma becomes receptive for a period of 12 hrs, the time available for cross pollination to occur. Flies belonging to the genus *Physiophora* are the main pollinator at the time of anthesis. The varieties are mostly self-compatible, but poor fruit set sometime occurs due to lack of insect pollinators. Plant growth regulators (PGRS) play an important role in regulation of different physiological process, growth, yield and quality of fruit crops (Suman *et al.*, 2017). Application of phytohormones especially GA and NAA at a concentration of 10-50 ppm is found to be effective in increasing the fruit set. The fruit is a berry and bears a single stone, the shape of fruit generally varies from round to oblong or oval in shape. The fruit skin is thin and may be smooth or rough with glossy appearance. They are first green and turn yellow as they ripen. At full maturity the fruit are red, juicy and soft and has a pleasant aroma and sweet taste (Pareek *et al.*, 2007). The fruit may be round, flat, obliquely beaked, pointed or bluntly tapering at the styler end whereas the stem end may be grooved or smooth depending on the cultivar. Weight of the fruit generally varies from 20 to 50 g.

Nutritive and medicinal value

The ber berry is highly nutritious, although, called as poor man's fruit; the nutritional value is at par with many other fruits (Panwar, 2012). The fresh fruit contains 13 to 20 % TSS and 0.2 to 1.0 % acidity. The fruit per 100 g contains energy 24.76 kJ (5.92 kcal), carbohydrates 17 g, sugars 5.4-10.5 g, dietary fiber 0.60 g, fat 0.07 g, protein 0.8 g; vitamins like Thiamine (B_1) 0.022 mg, Riboflavin (B_2) 0.029 mg, Niacin (B_3) 0.78 mg, other vitamins like vitamin C 120 mg, β-carotene (Vit. A) 80 µg; minerals like Calcium 25.6 mg, Iron 1.1 mg, Phosphorus 26.8 mg, Other constituents Water 81.6-83.0 g (Kavitha *et al.*, 2014). The fruits are generally eaten fresh and may also be eaten dried or candied. It may even be processed to prepare murabba, pulps, jam, candy, chutney, squash or nectar prepared from the pulp can also be served as beverages. The fruits of wild varieties particularly malahber (*Z. numularia*) are sun dried and are often sold during off season. Ber trees are often used for rearing lac insects, the leaves along with tender shoots are used as fodder and wood used as fuel. The tree also has different medicinal uses and parts like root, bark, leaves, flowers, seeds, *etc.* are used in ayurvedic and yunani system of medicines for treatment of ailments like diarrhoea, cough, ulcer, indigestion, headache, bleeding gums, asthma, *etc.* (Dalal *et al.*, 2019). It also acts as a blood purifier and appetizer.

Crop improvement

a. Genetic diversity: The center of origin of *Zizyphus mauntiana* is India, while of *Zizyphus vulgaria* is China. More than 600 species belonging to the genus *Zizyphus* are known out of which 18-20 are native to India. They are found throughout the country *viz*., *Z. apetala*, *Z. funiculosa* and *Z. incurve* are native to north eastern hills, *Z. mauritiana* and *Z. nummularia* found particularly in North Western India including U.P, *Z. oenoplia and Z. rugosa* in central and east-

ern India, *Z. Vulgaris* grows naturally in the North Western Himalayas, *Z. rupicola* is found in central and Eastern India and *Z. xylocarpus* in M.P. and Peninsular region as reported by (Pareek, 1988). Among all ber species *Z. mauritiana* is the most important fruit species and is widely cultivated in the tropical and subtropical regions of India (Singh *et al.*, 2007). Fruits of *Z. nummularia* and *Z. rotundifolia* are also edible and the *Z. rotundifolia* is used as rootstock.

b. Germplasm conservation: A lot of research work for improvement in the yield and quality of fruits is being done by different institutions across the country (Kalinganire *et al.*, 2012). Several germplasm including species and cultivars have also been collected and are being maintained in the field gene banks of CIAH, Bikaner; and NBPGR, Jodhpur; IAPKV, Rahuri; CCSHAU, Hisar; CAZRI, Jodhpur. CIAH, Bikaner has highest collections (338) of these and had been made available in the National Field Repository of ber (Bolada *et al.*, 2012).

c. Improvement approach: In India a large number of ber cultivars are cultivated and attempts have been made to identify superior cultivars based on their vegetative and fruit characteristics. As ber is naturally cross pollinated, it gives rise to natural hybrids having wide genetic bases. This is further augmented by high levels polyploidy in fruiting tree, which helps in creating large genetic variability. Attempts have been made by different institutions across the country for improvement of cultivars utilizing modern techniques including micro propagation.

d. Variety improvement: Varietal improvement programs have been under taken by different research institutions across India to develop superior high yielding varieties suitable for commercial cultivation. CAZRI, Jodhpur has a fair share in its efforts to develop superior ber cultivars; they evaluated more than 80 cultivars under varying rainfall conditions (150-500 mm). Cultivars with early ripening characteristics *i.e.* Seb, Gola and Mundia are recommended for low average rainfall (150 mm) regions. Late ripening cultivars are not suitable for rainfed areas having average rainfall less than 500 mm. some of the popular ber varieties are as under:

Goma Kirti: It is a high yielding and early maturing variety, which fetches good price in the market. It is resistant to various diseases and pests by virtue of its earliness.

Thar Sevika: It is a F_1 hybrid between Seb and Katha. Thar Sevika is an early maturing variety. The fruits are juicy, sweet with TSS content of 22-24%. Fruits after consumption do not cause throat soaring, which is common in other cultivars. Average fruit yield is 30-32 kg/tree. The hybrid is also suitable for staggered picking which can be done upto third week of January. It is developed by CIAH, Bikaner.

Thar Bhubhraj: It is a selection from local material of Bhusavar area of Bharatpur district of Rajasthan.

Gola: It is an early maturing variety, mainly grown in Delhi, Haryana and other adjoining areas. It bears medium sized round to oval excellent quality fruits which are greenish to golden yellow in colour at the time of ripening. The average fruit weight varies from 15-20 g and it yields up to 85 kg/tree.

Seb: It is an early maturing variety which bears round fruits, resembling crab-apple. Fruits are light pinkish yellow in colour with slightly rough skin and occasional specks at maturity. It yields up to 85 kg/tree.

Selected Safeda: This early maturing variety is popularly grown in Haryana and Punjab. It is resistant to powdery mildew disease. The fruit is medium sized and almost round in shape. The ripened fruits are sweet, fleshy and develop golden yellow to greenish yellow colouration at the time of ripening. The average fruit weight varies from 25-30 g.

Kaithli: It is a mid-season variety and is mainly grown in Punjab and Haryana. The fruit is medium in size and oval to oblong in shape. The fruit develops greenish yellow to golden yellow color on ripening. Mature fruits are thin skinned and sweet in taste. The fruit weight varies from 25-30 g and yields up to 125 kg/tree.

Sannaur: It is a mid-season variety and is mainly grown in Punjab and Haryana. The fruits are medium sized and oval to ovate in shape. The variety is resistant to powdery mildew. The average weight of the fruit varies from 25-30 g and it yields up to 100 kg/tree.

Meharun: It is a mid-season variety and is mainly grown in Gujarat. The variety is resistant to fruit flies. The fruits are medium sized and oval to ovate in shape. The fruit develops light yellow to greenish yellow colouration upon ripening. The average weight of fruit varies from 20-25 g.

Banarasi Kadaka: It is a very popular mid-season variety grown in Uttar Pradesh. The fruit are large in size and oblong in shape. The fruit develops yellow coloration upon maturity. The average weight of fruit varies from 40-50 g and it yields up to 125 kg/tree.

Umran: It is a late season variety mainly grown in Punjab and Haryana. The fruits are oval to elliptical in shape and large in size. The fruits develops golden yellow color on ripening. It is a high yielding variety with appreciable keeping quality. The fruits can be transported to long distances without significant damage and spoilage. It is also resistant to fruit flies. The weight of the fruit varies from 35-40 g and it yields up to 200 kg/tree.

Soil and climate

It is a very hardy fruit tree and performs well under adverse climate and poor soil conditions. It can be successfully grown in tropical and sub-tropical climate. The ber is peculiar for its ability to grow on wide range of soils (Bohane *et al.*, 2016). Deep sandy to sandy loams are best suited for ber cultivation. It can be grown up to a height of 100 m above sea level. Plants can tolerate soil salinity (pH > 9) and water salinity up to a limited extent. Ber can be grown satisfactorily in alkali soils characterized by high pH and sodicity. Application of gypsum @ 5 kg/ pit followed by flooding about one week prior to planting is recommended in such soils. Ber is highly drought tolerant fruit tree and can withstand to extremely high temperatures. Normally it prefers drier climate for good quality fruiting but can also be grown under tropical and subtropical regions of the country. Some of the ber species are also found in the foot hills of temperate regions. However temperature below freezing point is injurious to young plants as well as fruits. Areas receiving annual rainfall in the range of 400-650 mm are well suited for its cultivation.

Propagation

In ber T-budding is generally practiced at a height of 15 cm above the ground level during June to September. Lower most shoots/ sprouts emerging on the rootstock below the bud are to be removed frequently after budding. 50% of the tops may also be looped before removal of whole top above the union points after one month of budding. Successful buds should be single stemmed soon after the sprouting.

Cuttings: Treatment of green wood cuttings of Indian jujube or ber with 250- 500 ppm IBA, 250-500 ppm NAA results in 85 % rooting in sand and has a high percentage of survival (Shen *et al.*, 1992).

Budding: It is known to be the best method of ber propagation. Different type of budding techniques *i.e.* budding, ring, patch and forkert budding *etc*. (Pareek, 1978) have been used, but the best and widely accepted of budding is shield budding (T or I budding). The ring budding is cumbersome, as there is requirement of equal thickness of stock and scion for successful unions. The most widely used rootstock used in budding is *Z. rotundifolia* also known as Bordi. Slow growing rootstock *i.e. Z. nummularia* if used generally leads to incompatibility issues. The time of budding mainly depends on climatic variables *viz*., temperature, humidity and availability of budding material. There are chances of breaking of bud union if wind velocity is high. Therefore the best time for budding especially in Western Rajasthan is in the month of July (Pareek, 1983). Although an initial investment is very high but a net profit can be earned from ber nurseries provided there is guaranteed sale of plants at a reasonable price of Rs. 10 per budling (Singh *et al.*, 2004). Cultivars like ` Elaichi and `Gola' showed best compatibility with the local rootstocks and resulted in 100 % success with maximum in budling growth while Banarasi Karaka' gave lowest of 70% (Ghosh, 2009). The budded scion of Banarasi Karaka performs best in open conditions rather than shade. The month of May, June and September are best for *in situ* budding as cent percent success with maximum plant growth have been observed, while in the months of May and June a success rate of 75 to 85 % was observed.

Rootstocks: Stock and scion compatibility studies were carried in ber cultivars *viz*., Banarasi Karaka, Ponda and Gola with 3 rootstocks *viz*., Jhar ber (*Zizyphus nummularia*), (*Zizyphus mauritiana* ecotype-29) and (*Zizyphus mauritiana* ecotype-Assam Gauhati). The rootstock Jhar ber showed incompatibility with inverted bottleneck symptoms: budded with Gola cultivar. All other combinations were compatible with perfect unions. The histological studies of incompatibility showed that it is mainly due to absence of callus production between the rootstock and scion resulting into a wide gap and weak and unhealthy plants (Verma *et al.*, 2000). In another study *Zizyphus mauritiana* cv. Umran was budded on 12 rootstocks *i.e.* Five *Z. mauritiana* accessions obtained from different parts of India, Chinese. *Z. jujuba*, Argentinian *Z. zoaziroo*, Indian *Z. xylopyrus* and four accessions of *Zizyphus nummularia* from different regions of India (Bal *et al.*, 1997). Umran on *Zizyphus mauritiana* rootstock showed most vigorous growth and produced the highest cumulative fruit yield of 115-146 kg/ tree.

Raising of seedlings: Nursery seedling may be produced by soaking seeds for about 24 hrs in water, it promotes early and higher germination along with good vegetative growth in comparison with sowing of whole seeds (Mankar *et al.*, 1997). Cracked seeds also exhibit good germination, but germination percentage not at par with water soaking treatment. Conventional method *i.e.* budding usually takes about 13 months to raise plant, suitable for planting in orchards. High mortality while planting usually occurs in the field due to damage to the tap roots.

Seedlings may be raised *in situ*, but to cater damage while planting it's better to raise them in polythene bags. Seedling raised in polythene bags are budded and there after transplanted in the desired place. 90 days old seedlings are budded in July and they are ready for planting a month earlier.

Micro propagation: Different types of explants have been examined under *in vitro* condition to evaluate factors influencing regeneration of juvenile explants and callus of different species of ber. For leaf and cotyledon explants of *Z. mauritiana* and *Z. nummularia*, root and hypocotyl callus regenerated with relatively high concentrations of NAA and BA (2.5 and 0.6 ppm, respectively). High number of shoots from explants of both *Z. mauritiana* and *Z. nummularia* was observed on medium containing nitrate N at a concentration of 526.6 ppm. Singh *et al.* (2010) found that shoot tip explant was better than nodal and inter nodal explants. BAP (2.0 ppm), NAA (0.1 ppm) and GA, (0.1 ppm) were found to be best for shoot proliferation considering higher sprouting percentage, number of shoots, shoot length and leaf area in medium supplemented with these PGRs. For root induction percent, root regeneration, days to root initiation, root number and root length, medium supplemented with IBA (2.0 ppm) was found to be most effective.

Explants from stem of *Z. mauritiana* obtained from mature tree was best suited and rooting was induced by pretreatment with 50 µM IBA or 50 µM NAA for 24 hours, followed by transference to auxin-free White medium. The plantlets developed grew well in a soil and vermiculite mixture (Mathur *et al.,* 1995). Explants from inter nodal and nodal segments are most responsive on the medium containing zeatin followed by BA (Nisha & Srivastava, 1996). Leaf explants showed high callusing on medium supplemented with 0.25 ppm IBA and 2.5 ppm BA (Fougat *et al.,* 1997). For shoot tips, shoot growth and number of nodes decreased, while branching percentage increased with increasing concentration of BA (Sudhersan *et al.,* 2001). Buds of the small-fruited cultivar of *Z. jujuba* shows higher shooting percentage than medium and large-fruited cultivars. The best results were obtained in modified Pierik nutrient medium, with low BA and IBA concentrations. Cold treatment for 30 days in darkness facilitated embryo development and plant growth (Assareh and Sardabi, 2005). For shoot tips, the best results were observed on medium containing 2.0 ppm IBA or 0.05 ppm IAA + 1.0 ppm IBA. Temperature dependence of rooting with a rooting percentage of 99–100%, under a 12-hour photoperiod has been observed by Du *et al.* (1997).

A micro propagation protocol for *Z. spina-christi* has been developed by Sudhersan and Hussain (2003). It includes three distinct culture phases *i.e.* initiation and multiplication, shoot growth and elongation and root formation. Initiation and multiplication medium contained 0.1–1.0 ppm BA, Growth and elongation medium did not contain any plant growth regulator (PGR) while the rooting medium contained 10 ppm IBA. About 300 explants were obtained from a single shoot tip by the end of the three subcultures.

Planting: Monsoon season (July-September) is best time for planting of ber. In India plantation is done in square system, at a spacing of 6 x 6 m in low rainfall areas and 7 x 8 m and 8 x 8 m in the irrigated regions or in those receiving higher rainfall. In rain fed areas, shaping the interspaces between tree rows to provide 5% slope towards the plant helps accumulate run-off water during monsoon results in higher plant establishment and profuse vegetative growth. In irrigated areas (Punjab and Haryana), ber plants can also be transplanted from January–March also. In sandy soils, placing sub-surface barriers of bentonite clay reduces infiltration of water and thus increases success of plantation.

Irrigation: In rain fed areas water conservation is an important aspect of ber cultivation, arrangement for *in-situ* water harvesting should be done in the orchards by giving 5% slope to the inter-row spaces towards the trees. Ber plants have well developed deep tap root system and have xerophytic nature and once established, needs little care and irrigation. The harvesting of fruits is over by April and plants become dormant in May-June and shed their leaves. Ber trees need irrigation from November to February for better fruit development. They do not need irrigation during the fruit maturation. Black polythene mulch helps conserve soil moisture and improves growth of the trees. Irrigation during November-February at 3 to 4 weeks interval is done in irrigated areas of Punjab and Haryana, but irrigation during October causes significant flower shedding and during March-April causes fruit spoilage and delayed ripening.

Training and pruning: During the first 2 to 3 years after planting, ber trees should be trained to develop a strong framework. Old growth is removed during March keeping 1–2 nodes above the graft union to induce vigorous new growth. One upright growing vigorous shoot is retained to develop into main trunk which is kept clean of secondary branches up to a height of 30 cm from the ground level. On the main trunk, 3 or 4 well-spaced and favorably located main branches are allowed above when it is headed back. During the second year, these main branches are also clipped retaining 3 to 4 secondary branches on each one of them. This process is continued to develop tertiary branches. Upward growing shoots are retained at each stage to develop an upright tree stature. Not more than one upright growing shoot is retained at a node so that narrow crotches are avoided. This basic frame of the tree is maintained by removing of water sprouts as and when they emerge. Correction in the framework is done at the time of annual pruning. Ber bears fruits on new growth at the axil of the leaves. Therefore, to get optimum growth and yield regular training pruning is essen-

tial. The pruning should be done after 15th May as it improves growth of the tree and fruit quality. If left unpruned the ber trees becomes unproductive and laggy. It has been seen that un-pruned trees may have 10 meter long scaffolds and very little foliage and bear fruit at the tops only. It is essential to remove about 30 percent of the growth of the preceding years. The intensity of pruning in irrigated orchards improves fruit quality as observed by Bisla *et al.* (1991). Singh *et al.* (2004) observed appreciably higher fruit yield from plants pruned on 15th April and mean average yield was 180.3 kg per tree in cv. Sanaur 2. The ber trees are deciduous and are in dormancy stage during May and June and level of reserve metabolites such as carbohydrates, starch and sugars is higher during this phase of dormancy. Pruning during this period can lead to more growth, higher fruit set, and greater yield. Delay in the time of pruning results in lower yield and poor quality fruits, but severely pruned fruit trees produces significantly lower fruit yields than the light pruned plants (Kumar *et al.*, 2002).

Manuring and fertilization: In ber orchards productivity of trees can be improved if manuring is done every year. The dose varies with fertility status of different locations. A dose of 750g N/tree gives highest yield, whereas 250 g N and 250 g P_2O_5 significantly increases fruit yield. Higher plant height, spread, trunk girth, fruit set and fruit retention was recorded with the soil application of recommended FYM + 100% NPK +Azotobacter + PSB in comparison to recommended FYM+ 75% NPK + Azotobacter + PSB (Mahendra *et al.*, 2009). The maximum improvement in soil nutrient status *viz*., organic carbon, N, P. K, Ca, Mg and minimum soil pH and EC was observed with soil application of FYM + 100% NPK + Azotobacter + PSB which was at par with recommended dose of FYM + 75% NPK + Azotobacter + PSB treatment. The nitrogen content is significantly influenced with the application of N in orchard soil (Haridayal *et al.*, 2010). The yield of ber significantly increases with the application of N, P and Zn sulfate.

Weed control: In fruit orchards, weeds are a major hindrance as they starve fruit plants from nutrition, moisture and light. These weeds can be managed by following different strategies, *viz*., chemical, mechanical, manual, mulching and biological methods *etc*. Although chemical weed control as a method for weed management is highly effective and easy, it has its own constraints *viz*., crop injury, soil and water residues, human health apprehension and development of resistance to herbicides (Pot *et al.*, 2011). Manual weed management in present scenario is very expensive and labor intensive. Mechanical weed control is an effective means for short term weed management however in well-established orchards it is quite difficult and less efficient owing to spreading tree canopies as well as limited coverage by agricultural equipment and high chances of potential damage to root and shoots of fruit trees. Shallow ploughing results in less harm to the tree roots, the tillage of orchard floor using rotavator also gives good results. Presently most of the fruit growers rely mainly upon mechanical weed management using adjustable rotavators as this machine not only performs shallow ploughing but also has wider coverage under tree canopies. Covering the soil surface with mulches in the orchards is a safer method as compared to herbicide application (Ramakrishna *et al.*, 2006). Organic mulches are easily available and are cheap in comparison to plastic mulches, which are costly for weed management in orchards. Moreover organic mulches are beneficial for optimum plant growth and yield and improve quality of fruits in addition to being a highly effective method for weed control. Most of the weeds remain under check in summers, due dormant nature of the ber tree. However, perennial weeds like baru grass, dubh grass, parthenium and puthkanda, *etc*. causes substantial problem during growing period of trees. Diuron, Glyphosate and Paraquat at 3-4 kg/ha significantly decreased weed population in ber orchard and increased fruit yields (Bajwa *et al.*, 1993). To control perennial weeds spray of Round Up (glyphosate) @ 10 ml/ litre or Gramoxone @ 6 ml/ litre when the weeds have attained sufficient vegetative growth (20-30 cm height) has been recommended.

Intercropping: The interspace between the rows of fruit trees in ber orchards can be utilized for growing intercrops as after planting of ber plants 4 to 5 years are generally required to cover the interspace between the trees. Leguminous crops are preferably the best choice and are taken as intercrops in ber orchards as they enrich the soil in addition to income generation during the period of orchard establishment. Inter cropping in ber plantation on results in higher yield and monetary return, if chosen wisely. Irrespective of the intercrops, ber based intercropping system recorded a 7.0 % higher ber fruit yield than. Similarly, ber based intercropping system recorded 19.6 % more ber fruit equivalent yield than sole ber system (Patel *et al.*, 2003). Among the different systems evaluated ber+green gram gave the highest net monetary return (Rs. 13099/- ha) followed by ber+sorghum system (Rs. 11,886/-ha). Intercropping in ber recorded on an average 10.0 % higher monetary returns (Rs. 11329/ ha) over ber sole system (Rs. 10287/- ha) per annum. Singh, 1997 reported that initial fruit yield in the intercropped ber orchard increased up to 3 times (14.8 kg/ tree) compared with the control (5.2 kg/ tree). Intercropping in newly planted ber orchard had no adverse effects on plant growth for up to 5 years. Ber + cluster bean-mustard is a compatible combination with respect to sustainable yield, optimum returns, multiple outputs and improvement of site conditions (Saroj *et al.*, 2003)

Rejuvenation of old orchards: It has been observed that engineering of tree architecture, canopy density and photosynthetic efficiency play an important role in governing

the fruiting potential in fruit trees (Lal and Mishra, 2008). Several reports on rejuvenation by pruning, canopy management, dehorning and top working are available in different fruit crops *i.e.* mango, guava, aonla, litchi, peach, apple and ber. The morphological attributes of fruits obtained from rejuvenated trees in ber orchards was significantly better than fruits obtained from non-rejuvenated trees. Singh *et al.* (2015) while studying rejuvenation in Umran, Gola and Seb cultivars of ber found that fruit weight, fruit length, stone length, pulp content and pulp : stone ratio were higher in cv. Umran followed by Gola and Seb, whereas, fruit and stone diameter and stone weight was higher in cv. Gola. Variation in physical parameters of fruits obtained from rejuvenated trees of different cultivars may only be due to their genetic characters. The chemical attributes *i.e.* TSS, TSS : acid ratio and total sugars was slightly higher in fruits from non-rejuvenated trees in each cultivar but the differences were non-significant. However, ascorbic acid content was higher in fruits obtained from rejuvenated trees. The TSS and TSS: acid ratio was higher in cv. Seb, whereas, acidity, total sugars and ascorbic acid contents were found higher in cv. Gola. The technology helps in maintaining the manageable tree height with open architecture and canopy of healthy shoots with outwardly growth facilitating maximum light penetration and its utilization by the plant. Growth of new healthy shoots and luxuriant leaves tend to exhibit high photosynthetic efficiency thereby, keeping a balance between vegetative and reproductive growth which ultimately might increase tree canopy volume, yield and quality of fruits in rejuvenated trees.

Flowering, floral biology and fruit set: The flowering period of ber varies from early June to late November in different cultivars under different agroclimatic conditions. Flowers are borne in the axil of leaves of mature as well as current seasons shoots. The life of individual flower in an inflorescence is very short and many flowers remain unpollinated during their receptive periods. Flowering usually occurs about 21 days from early bud development and length of flowering ranged from 57 to 75 days, depending on cultivar. The mode and time of anthesis is also cultivar specific and may be influenced by environment. Anther dehiscences start about 2 hrs after anthesis and continue for about 2 to 4 hrs. High pollen viability has also been reported in different ber cultivars. Stigma shows peak receptivity at the time of opening of the flower.

Fruit growth and development: Physical and biochemical changes occurring in growth and development of ber fruits have been extensive investigated. Ber fruits follow a double sigmoid growth curve. Fruits are ready for harvest, when having a specific gravity of <1; organolpetic tests also assists in judging maturity of the fruit. Fruit drop also occurs due to lack of fertilization (Singh *et al.*, 2005), to maintain a crop load the tree can sustain (Vashishtha and Pareek, 1979), soil moisture stress, frost, high and low temperature. Fruit set increases with the application of IAA @ 100 ppm IAA also removes cross incompatibility problems in ber and IAA treatment also results in increased fruit retention and decreased fruit drop in ber.

Pests: Butani (1979) recorded 80 insect species feeding on ber trees in India. Lakra and Singh (1983) opined that commercial cultivation of ber has become difficult due to attack by more than 100 species of insect pests in north India. Although ber is infested by a large no of insects, yet only few species have attained the status of the pest and cause substantial damage to ber some of the important pests are as under:

Fruit flies (*Carpomyia vesuviana*, *Dacus correctus* and *D. dorsalis*)**:** Among these *C. vesuviana* causes as much as 80% damage to the fruits, under severe. It is the most serious pest of ber. Infestation starts with the onset of fruit setting. The adult female lays eggs singly by inserting its ovipositor into the young developing fruit. The larvae on hatching after 2 to 5 days, start feeding on the pulp and make galleries in it. The excreta of the larva accumulate in the galleries, which may result in rotting of the fruits. Infested fruits become deformed and their growth gets arrested. A large number of such fruits drop off from the trees causing significant reduction in the yield. To prevent infestation, prophylactic sprays may be carried out with 0.03 % oxydemeton or dimethoate starting from the stage when 70-80 % fruits attain pea size and then repeating the spray at one month intervals (Pareek and Nath, 1996). During the maturity of fruits, if necessary, spray with 0.5% Malathion+0.05% sugar solution at weekly intervals.

Fruit borer (*Meridarchis scyrodes*)**:** Damage by larvae of the fruit borer has been observed mainly in southern and western India (Pareek and Nath, 1996). The reddish larvae bore into the fruit and feed on the pulp and accumulate faecal frass within. The moths are small, dark brownish in colour. Pest incidence shows positive correlation with temperature while negative relationship of the incidence of the pests was found with relative humidity, wind speed and cloud cover (Nandihalli *et al.*, 1996). Collection and destruction of fallen fruits and digging the orchard soil under the tree canopy have also given good results. Chemical control consists of first spray at pea stage with monocrotophos (0.03%), second spray after 15 days with fenthion (0.05%) and a third spray 15 days after the second spray with 0.01% carbaryl has been recommended (Pareek and Nath, 1996).

Bark eating caterpillar (*Indarbela quadrinotata*, *I. watsoni* and *I. tetraonis*)**:** The caterpillars have been reported

to make winding galleries of frassy web on the stem near the forks and angles of branches. The caterpillar is hidden in the stem in the day-time and becomes active at night, eating the bark. Heavy infestation by this pest stunts the trees and adversely affects fruit yield. Frassy galleries caused by the pest needs to be removed and cleaned. Then 0.05% monocrotophos is painted on the bark, followed by 0.2% trichlophos and 0.05% chlorfenvinphos (Verma and Singh, 1975). Application of the solution, made up by mixing one litre of kerosene and 100 g soap in 9 L of water, to the holes has been found to effectively control the bark eating caterpillar. Alternatively, each hole should be filled with a solution of 2 ml monocrotophos or 20 ml trichlorphon 50 EC or 30 ml endosulfan 35 EC in 10 L of water and then the holes closed with mud (Azam-Ali *et al.*, 2006).

Hairy caterpillars (*Dasychira mendosa*, *Euproctis fraterna*, *Thiacidas postica*)**:** Hairy caterpillars feed on the young leaves and fruits. The older caterpillars spread in all directions and devour leaves and fruits and sometimes even tender shoots. They start eating new foliage as it grows after pruning and this is continued by overlapping generations. BHC 10% can be dusted to control caterpillars in the young stages. All the instars can be controlled by treatment with 0.1% carbaryl or endosulfan or trichlorphon or 0.05% methyl parathion (Verma *et al.*, 1972). A spray of 0.05% monocrotophos and 0.2% carbaryl (Killex carbaryl 50 WP) is most effective in controlling the pest (Pareek and Nath, 1996).

Diseases

Ber is affected by many serious diseases like powdery mildew, sooty mold, leaf spots (*Alternaria, Cercospora, Septoria, Cladosporium, Pestalotiopsis*, *etc*.) and rust among the fungal infections and witches broom caused by MLOs. Powdery mildew (*Oidium erysiphoides* var. *zizyphi*) is an economically important disease of ber, which results in 50-60% loss in fruit yield and reduces market value of the produce. The disease is known to be severe in early pruned crop (April first fortnight) and is generally favoured by rainfall, warm humid conditions proceeding to its appearance on fruits during September to December. The disease can be effectively managed by alternate sprays of triadimefon at 0.1% followed by wettable sulphur at 0.3% at an interval of 12-15 days. Among many genotypes, Jogia and Mundia were found resistant while, popular cultivar Umran was highly susceptible and another cultivar Kadaka was moderately resistant to powdery mildew. Among the other diseases, sooty mold caused by *Isariopsis inidica* var. *zizyphi* causes sooty/black spots on leaf surface covering large area of leaves, often resulting in defoliation and reduced yields. The leaf spots caused by *Cercospora zizyphi* and *C. jujube* cause circular oval spots on leaves whereas *Alternaria chartarum* forms small irregular brown spots resulting in defoliation. These diseases can be managed by carbendazim at 0.2% spray. The rust (*Phakopsora zizyphi-vulgaris* Diet.) causes small irregular reddish brown pustules covering entire leaves resulting in drying and defoliation. The disease can be managed by spraying mancozeb at 0.2% or zineb at 0.2% or wettable sulphur at 0.2%. Witches broom, a MLO disease causes phyllody of plants producing auxillary bud proliferation giving bushy appearance and transmitted through grafting.

Harvesting and yield: Harvesting of fruits at proper stage of maturity is of much important both for maintaining quality and marketing. Ripening of fruit may take place either before or after harvest, but it is generally accepted that post-harvest ripening of ber only occurs if the fruit is sufficiently mature when picked. Immature fruits do not have desired sweetness and taste, over mature fruits on the other hand loses attractiveness and crispiness and become slimy in texture within a very short span (Pareek, 2001). Fruit colour, percentage of titrable acids and total soluble solids are important maturity indices for ber fruits, but specific gravity of the fruit and fruit colour are more suitable indices for determining maturity Ber plants start fruiting after first year of plantation in budded plants while seedling plants takes 3-4 years to come to fruiting. However, commercial production starts from third year onwards, hence the first year fruiting should not be allowed. The fruits of ber do not mature after harvesting. It is therefore, essential to harvest the fruits at an optimum stage of maturity. Harvesting is difficult in ber due to spiny nature of plants but the fruits are picked manually. Harvesting of fruits by shaking of fruit laden branches is also adopted. Under rainfed condition average yield per plant ranges from 10 to 52 kg with a rainfall of 125 mm and 850 mm respectively. However, under irrigated condition an average yield of 150-300 kg per plant (30-60 t ha^{-1}) can be obtained depending upon cultivar and location.

Ripening and storage: The ber fruits can be stored safely for about one week at room temperature and for about three weeks under cold storage. A 20 days storage period can be achieved by the combinations of 1% and 2% Ca with polyethylene bag under zero energy cool chamber was found to be effective in maintaining better quality of the fruit throughout the storage period in term of retention of acidity, ascorbic acid and total sugar (Bhasker *et al.*, 2006). Singh *et al.* (2008) observed that the Treatment with calcium nitrate (1.5%) and kept in the PPE (perforated polyethylene) bag is most efficient to retaining fruit quality, this treatment showed 21.3 and 10.8% PLW in Gola and Goma Kirti cultivars, respectively. Randhawa *et al.* (2009) observed that physiological loss in weight increases and fruit firmness decreases during storage. Fruits can be stored up to 20 days by pre-harvest spray of $CaCl_2$ (2%) and GA, (60 ppm) treatment, with min-

imum loss in quality. Vithlani and Patel (2010) found that titrable acidity, Flavonoid content, Flavonol content, DPPH radical scavenging capacity and ABTS radical scavenging capacity increased significantly in jujube wine and vinegar as compared to fresh jujube juice, while significant decrease in pH, total carbohydrate content, total phenol content and ferric reducing antioxidant power was observed during the same time period. The shelf- life of fruits can also be enhanced up to 30 days if the fruits are treated with 6 percent wax-emulsion and packed in perforated polythene bags of 100 gauge thickness, before storing in the commercial cold storage (7-8°C) and 85-90 percent RH.

Grading and packing: After harvesting of ber fruits, grading should be done to remove the undersized miss-happened, cankered and wind damaged fruits. 3-4 grades are generally used for grading *i.e.* A grade best fruits of large size, B-grade-medium sized good coloured fruits, C-grade small sized well coloured fruits and D-grade poorly coloured fruits of all sizes and left outs. The highest percentage of fruit falls in B-category followed by A grade. C and D grade may have just equal quantities. The A and B grade fruits are preferred in the market as well as by the consumers. A B and C grade fruits should be packed in corrugated fiber Board (CFB) cartoons, wooden crates, plastic crates, polynets or baskets of convenient sizes. D-Grade may be marketed in gunny-bags.

Value addition: Selling the products at the lowest market value just to survive economically is not sustainable. It can lead to stress on the land as well as on the farmer. Value-addition is simply anything we can do to raise the value of our product in the market. Value-added practices are the key to the future of sustainable farming, because they enable growers to advance economically. As a result of the change in physical state or the manner in which the agricultural commodity or product is produced and segregated, the customer base for the commodity or product is expanded and a greater portion of revenue is derived from the marketing, processing or physical segregation which is available to the producer of the commodity or product. It improve the profitability of the farmers, reduces the glut in market during peak season. Produce that cannot be stored can be converted into value added product increasing the profit margins of the farmers. This helps in empowering farmers and other weaker sections of society especially women through gainful employment opportunities and revitalize rural communities apart from providing better quality, safe and branded foods to the consumers, reduction in post-harvest losses, reduction of import and meeting export demands. Value addition encourages growth of subsidiary industries and reduces the economic risk of marketing thereby increasing opportunities for smaller farms and companies through the development of new markets.

Ber has immense potential in sustaining the income for farmers of arid and semi-arid regions of India by value addition. Procedure for ber candying was standardized by Singh *et al.* (1944), results showed that candy treated with sodium meta-bisulphite scored higher than those blanched with hot water. Ber Jams are most popular fruit preserves it is prepared from whole fruit, pieces of fruit, fruit pulp or fruit puree and with or without fruit juice or concentrated. Fruit juice as optimal ingredients and mixed with carbohydrate sweetener, with (or) without water and processed to a suitable consistency. Dubey *et al.* (2014) evaluated the quality of ber jam during storage period. The physicochemical attributes of ber jam showed that there were slight differences in the various constituents of ber jam made on 0.2 and 0.3% citric acid.

Ber fruits have high nutritive value, especially carbohydrates and vitamin C with good amounts of minerals like phosphorus, calcium and iron and high sugar to acid ratio at fully ripe stage. These attributes are ideal for a fruit to be dehydrated. Kumar and Nath (2002) studied dehydration of ber fruits and reported that there was non-significant difference in pretreatment and osmo-drying on fat content of ber fruits. The ash content of pre-treated air dried fruits was highest (0.63 %) as compared to untreated osmo dried fruits (0.51 %) and pre-treated osmo air dried (0.43 %). For making a superior dried product with ber, the fruits should be blanched for 5 minutes in boiling water before dehydration (Pareek, 1983).

Khurdiya (1980a) studied the effect of dehydration on different cultivars of ber *i.e.* Umran, Bagwari and Chhuara they were good for drying. Fruits having golden yellow to reddish brown colour were found superior for drying. Sulphuring at the rate of 150 g/ 8 kg of fruits was considered optimum. The rate of browning increased during storage for 6 months at room temperature (21-38°C). Chawan *et al.* (1993) studied processing of ber and papaya and indicated that the overall organoleptic score of ber tuty-fruity was better than that of papaya tuty-fruity. Kumar (2006) prepared ber powder by dehydrating ripe ber fruits using sun drying and oven drying techniques with different pre-treatments and reported that the powder contained total sugars 57.38%, reducing sugars 36.98%, non-reducing sugars 20.40% and ascorbic acid 35.17%. Kumar and Nath (2002) developed the conditions for preparation for chuhura like products from ber by osmo-air drying process.

Powder of Umran variety of ber was used for the development of value added products due to superior qualities. The products were developed under four categories which included traditional (custard and kheer), baked (biscuits and cake), extruded (pasta and noodles) and unfermented beverage (RTS beverage) by using different concentrations of ber powder. All the baked products had good acceptability scores. The traditional products and extruded products were best acceptable up to 30% supplementation while and

unfermented beverage up to 20% supplementation with ber powder. Results of nutritional analysis indicated that all the nutrients content increased as the supplementation level of powder increased except the protein content of baked and extruded products. All the stored products were organoleptically acceptable except RTS beverage prepared using 40% ber powder. Biscuits prepared with 10, 20 and 30% and pasta, noodles and RTS beverage prepared with 10 and 20% ber powder were best acceptable among all during storage. Fruit based beverages are becoming increasingly popular in the market with the growing consciousness of people in the nutritive value of fruits (Srivastava and Kumar, 2002). Investigations on preparation of various products from ber fruits (*Zizyphus mauritiana*) were conducted by Bal and Ranadhava (2005). They concluded that the juicy varieties such as Sanour-2, ZG-2, and Kaithli can be converted into pulp to serve as base material for squash. Khurdiya (1980a) studied a ready to serve (RTS) beverage containing 33.3% juice prepared from dried ber fruit after cooking and extracting the juice in a basket press. The juice had a pH of 3.75 and 19.6° Brix with 0.56% acidity. The juice extracted from ber fruits and processed at 80°C for 10 min. stored well for 9 months at room temperature (20-38°C). The beverage was organoleptically acceptable on evaluation.

Ber fruit are highly mucilageous, have low acidity and are not ideally suitable for pickling. Shobha and Bharati (2007) standardized the procedure for pickling of ber as a form of value addition. The acidulants used in pickle preparation were lemon and salt and three variants were prepared with varying concentrations of salt, lemon and spices. When freshly prepared, vinegar based pickle scored maximum for texture (2.73) and taste (2.86) compared to lemon based pickle. Lemon treated pickle was better accepted up to three months of storage compared to vinegar based pickle, both at the laboratory and consumer level. With the advancement of storage the loads of bacteria increased in pickle with lemon as acidifying agent. There were no fungal colonies in the vinegar added pickle throughout the storage period.

Conclusion

Ber (*Ziziphus nummularia*) holds immense potential for increasing the income of farmers in arid and semi-arid regions of India. This fruit boasts a range of diverse properties and uses, including neurological benefits (such as hypnotic, sedative, and anxiolytic effects), hypotensive and antinephritic properties, cardiovascular activity, immunostimulant effects, and various anti-fungal, anti-diabetic, anti-allergic, anti-ulcer, anti-inflammatory, anti-spastic, antioxidant, and antibacterial activities.

The applications of ber extend beyond its role as a food ingredient; it is also widely used in traditional medicine. This knowledge has been passed down through generations and may or may not be rooted in an understanding of the fruit's constituents. In regions where ber production is abundant, its traditional medicinal uses are particularly culturally relevant. The fruit is employed in Ayurvedic medicine as a tonic, aphrodisiac, and laxative, and it is known to alleviate biliousness, burning sensations, thirst, and vomiting. Additionally, it is beneficial in treating tuberculosis and blood disorders. The seeds of the ber fruit are used to treat eye diseases and can also be helpful in cases of leucorrhea. Ber is utilized in various forms in different countries around the world, earning it the titles of "king of arid fruit" and "desert apple."

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