Production, Protection and Processing of Bael

Devendra Pandey, A. K. Mishra, P. K. Shukla,
Gundappa and Neelima Garg

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ICAR-Central Institute for Subtropical Horticulture
Rehmankhera, Lucknow-226101

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Composing

Subhash Pandey

Cover design

A.K. Misra

Preface

Horticultural crops contribute around 28 per cent of the GDP from a cultivated area of about 13.1 per cent. Bael is one of the important horticultural fruit crops of India, which comes under minor fruits category. Bael is bestowed with the pride of being sacred and denotes emblem of prosperity and its mention is available In ancient Sanskrit literature. The trifoliate leaves of bael resembles the trishool of Lord Shiva and thus it is offered during worshipping him. A wide range of bael genetic diversity exists in India. Variability exists in fruit shape, size, bearing habit, pulp colour, texture, fiber content, sugar content, mucilage content, etc. in different genotypes. This variabilty has to be utilized for developing high yielding varieties. In recent years, some good selections have been made at ICAR-CISH, which may be used for commercial cultivation.

Despite this historic and mythological significance, bael fruits have also been documented as an important ingredient of Indian medicine because of its high medicinal and nutritional value. Furthermore, every part of the tree is used in some or other way and could be considered as a Kalpvriksha. The ripe fruit is a restorative, laxative and good tonic for heart and brain. The fruit is prescribed in hepatitis and tuberculosis and proved effective in chronic diseases. The unripe and roasted dried fruit pulps is regarded as astringent, digestive, demulcent and stomachic, antipyretic and usually prescribed for diarrhea and dysentery. The leaf extract is effective in restoring blood glucose and body weight to normal levels. The root extract of bael has anti-inflammatory and wound healing properties while, the bark of the tree is used to treat diabetes in Indonesia. Therefore, several Ayurvedic preparations have some ingredients of bael either fruits, leaves, bark or root and their combinations. Processed products such as murabba, squash, jam, candy, syrups, etc are prepared from bael fruits.

Bael has bright prospects of cultivation in India due to its medicinal value and its ability to grow well under the waste land and problem soil conditions. It is also important to develop awareness at global level to promote its export. In the recent past, several innovations and new initiatives have been made in research and development for the production of bael. This publication is attempted to incorporate all relevant information in crisp form related to bael production and utilization chain, right from nursery management to postharvest management. The publication "Bael Cultivation" deals with the concept of good agricultural practices to be followed for higher production. The information is provided in a simple form so that the farmers can also understand and use for bael cultivation. Hence, this document is expected to be highly beneficial to scientists, farmers, teachers and students.

(S. Rajan)

Contents

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Introduction

Bael [Aegle marmelos (L.) Correa] is native to India and is widely distributed throughout the country in 8 states such as Uttar Pradesh, Bihar, West Bengal, Rajasthan, Madhya Pradesh, Uttaranchal, Chattisgarh and Odisha. Globally it is also cultivated in minor scale in countries like Sri Lanka, Pakistan, southern Nepal, Burma, Bangladesh, Vietnam, Laos, Cambodia, Thailand, the northern Malay Peninsula, Java, Timor Leste, the Philippines, Fiji, etc.

Though bael is a fruit crop of subtropical origin, it has shown wider adaptability to even tropical, arid and semi-arid regions with good performance. In India, it is mainly found in wild and semi-wild conditions especially in dry forests of hilly terrains and in some plains. It is also -found in the homestead gardens, backyards and Hindu temples.

In ancient Sanskrit verse, it is considered auspicious, sacred and symbolizes emblem of prosperity. Bael leaf is botanically trifoliate compound leaf which resembles the trishool of f Lord 'Shiva' and hence, it is used for worshipping the diety in temples. There is also a belief among Hindus that the three lobes symbolize the heads of Brahma (Creator), Vishnu (Protector) and Sanatana (Destroyer) . The history of bael tree has been traced to vedic times (C 2000 BC - C 800 BC) as the mention of this fruit was found in Yajur Veda and Buddhist and Jain literatures (C 800 BC - C 325 BC). In Ramayana period, - it was quoted that the fruit was found in Chitrakute hills and Panchvati which was used along with other fruits by Lord Rama to -while worshipping Lord Shiva. The fruits were found to have been portrayed in paintings of Ajanta Caves along with other fruits. In the 'Upayana Vinod', a Sanskrit treatise and in the 'Brihat Samhita' mention had been made of bael fruit. It was stated that this tree indicates the presence of underground water.

Fairly rich and well drained sandy loam soils are best suited for bael cultivation along with sunny and warm humid climatic conditions. However, owing to its hardiness, it was found to be suitable in a wide range of soils viz., sandy, clay, stony, acidic, alkaline, salt affected soils and wastelands etc. (Pandey and Misra, 2006, 2007; Pandey et al., 2008). This indicates that Bael is ecosystem friendly tree species which can grow in a wide range of soil conditions (pH range 5-10) and harsh environments such as areas with long dry spells and high temperature zones.

Bael belongs to family Rutaceae. It occupies an important place among the indigenous fruits in India since prehistoric time. In India, it is also

known in different common names such as Bengal quince, Indian quince, maredoo, golden apple, holy fruit, stone apple, bael, belwa, sriphal, etc. All parts of plant viz., leaves, roots, bark, fruits, seeds etc. are used as an important component of many Ayurvedic medicines.

Bael fruit is nutritionally rich in protein, fat, minerals such as Ca and Fe and vitamins mainly riboflavin, β carotene and Vitamin C. Fruits are used to improve the digestion and cure stomach diseases. Fruits can be processed into various beverages and preserves. Despite its Indian origin and utilization for its high medicinal and nutritional values, there is no well organized orcharding of bael reported in the country. More importantly, bael possessing the quality of adopting to adverse environmental conditions, can be promoted for development of waste and underutilized lands, since it has the reputation of thriving where other fruit trees cannot survive (Pandey et al., 2008; Pandey and Misra, 2015).

Uses

Bael has significance of high medicinal, pesticidal and nutritional values. It could be regarded as potential kalpavrksh as every part of the tree is important and has some potential use. Its medicinal properties had been detailed in "Charak Samhita". The ripe fruit is used as a restorative, laxative and thus used as a good tonic for heart and brain health. Fruit is prescribed in ailments of hepatitis and tuberculosis and also has proved to be effective in chronic diseases, even when other medicines fail. Aqueous and alcoholic extract of bael fruit have been noted to possess cardio tonic effect on mammalian hearts. Herbal drugs made out of bael were used to cure diabetes in pregnant and nursing mother. Homeopathic drugs, Aegle marmelus and Aegle folia are prepared from bael fruit and leaves, respectively. By incorporating bael fruits in the diet of growing infants and children under 3 age, their teething problem could be resolved. The unripe and roasted dried fruit pulps are considered as astringent, digestive, demulcent, stomachic, and antipyretic properties, because of which they are usually prescribed for curing diarrhea and dysentery. The leaf extract is effective in restoring blood glucose and body weight to normal levels. Green bael fruits are used for preparing murabba (preserve) generally taken for stomach ailments.

Bael fruits have immense potential for processing and several products such as squash, jam, candy and syrups can be prepared from it for foreign markets. The root extract of bael has anti-inflammatory and wound healing properties while, the bark of the tree is used to treat diabetes in Indonesia. Gum is extracted from seed locules and its potential use as adhesive, water proofing and oil emulsion coating was reported in 1961, which includes

r. Wood of mature tree has timber value and is used for making small agricultural implements. The leaves are used as a fodder for sheep and goats.

Composition of bael fruit

The bael fruit is highly nutritious, as mentioned in Table 1.

Table 1. Nutritive value of bael fruit

Constituent	Value (per 100 g pulp)
Moisture	61.5 g
Protein	01.80 g
Fat	0.30 g
Fiber	2.90 g
Minerals	1.70 g
Carbohydrates	31.80 g
Mucilage	12.7-19.0%
Carotene	55.0 mg
Thiamine	0.13 mg
Riboflavin	1.19 mg
Niacin	1.1 mg
Vitamin 'A'	186 IU
Vitamin 'C'	8-18 mg

Gopalan et al. (1971)

The bael fruit has the highest level of riboflavin. No other fruit has such a high content of riboflavin. Marmelosin is the therapeutically active principle of bael. Rind of bael fruit yields tannin. The fruit gives 88 calories of energy per 100 g of fruit pulp. The pulp of ripe fruits is tasty and can be consumed as a fresh or made into 'Sherbat' which is one of the most popular drinks for Indian masses.

Origin and distribution

Bael is indigenous to India and known since prehistoric time. The fruit is mentioned in the ancient Indian literature i.e., Vedas, Ramayana, Upvan Vinod and Brihat Samhita. It is found growing in neighbouring countries like Nepal, Sri Lanka, Pakistan, Bangladesh, Myanmar, Thailand and most of the South-East Asian countries. Because of its status of sacred tree, it is also grown in Sri Lanka and Northern Malaya, the dry area of Java and to a limited extent in northern Luzon in the Philippine Island. It is grown in some Egyptian garden as well as in Surinam and Thailand. In India it is cultivated throughout the country and main bael growing states are

Uttar Pradesh, Bihar, Jharkhand, Madhya Pradesh, West Bengal, Odisha, Chhattisgarh and Rajasthan. Systematic orcharding of bael is very limited, however, it is generally grown in temples, gardens roadside, backyards of houses, parks, etc (Singh and Roy, 1984).

Area and production

The organized orchards of bael are rare. Hence, the exact data on area and production is not available. In the recent years, initiatives have been made by some institutions for collection, evaluation and conservation of germplasm at their experimental farms. Some progressive orchardists have also started planting improved bael cultivars in the form of small orchards. Generally, the bael plantations were made as boundary plants or temple side or in home garden. Some seedling plantations were also available in natural forest and road side areas. The total production per year is estimated to be about one thousand ton in India (Saroj and Awasthi, 2004).

Botany and morphology

Botanically, bael is known as Aegle marmelos Correa and belongs to the family Rutaceae with 2 or 3 species falling within this genus. The generic name Aegle is of Greek origin while the species name marmelosis is of Portuguese origin. Its chromosome number is X= 9 and 2n = 36. . The tree is deciduous in nature with a height of approximately 6-8 meter possessing whitish/grayish stem and trifoliate aromatic leaves. The leaves are divided in to three leaflets i.e. a pair and terminal one. The branches are usually long, shallowly furrowed, corky and having thorns.

The flowers are 2 cm wide, bisexual in nature, borne in cluster and greenish white in colour with sweet scented aroma (Fig 1). The calyx is shallow with 5 short, board teeth and pubescent-exterior. Petals are usually 5 (rarely 4), and oblong, oval, blunt, thick, pale greenish white and, dotted with glands. Stamens are numerous, sometimes coherent in bundles and ovary is oblong-ovoid, wide with slightly tapered the axis. Cells are numerous, 8-20 in each ovule, small and arranged in a circle.

Fig.1. Bael Flowers

Fruit are hard shelled berry usually globose (2-4 inch diameter) with a nearly smooth pericarp. Pericarp of bael fruits are usually 3 mm thick, hard and filled with soft and yellow fragrant pulp. Seeds are numerous, compressed and closely packed in tiers and the shell surrounded by very tenacious, slimy, transparent mucilage which later becomes hard when dry. The testa is white with wooly hairs and the embryo has large cotyledons. (Pandey et al., 2016).

Germplasm status and conservation

Naturally grown bael seedlings are available in U.P, Bihar, Jharkhand, M.P, Orissa, West Bengal and Chhattisgarh with great diversity, which needs exploitation. In U.P., Faizabad, Sultanpur, Gonda, Jaunpur, Deoria, Pratapgarh, Allahabad, Varanasi, Mirzapur, Etawah, Mathura and Agra are the districts where large number of the improved types are growing naturally or planted in the backyard of the houses.

Germplasm of bael has been collected from several states, especially, from the parts of Uttar Pradesh, Bihar, Jharkhand, Gujarat, Haryana, Madhya Pradesh and West Bengal by NDUA&T, Kumarganj, Ayodhya; ICAR-CIAH, Bikaner; ICAR-CISH, Lucknow; CCSHAU, Regional Research Station, Bawal, Rewari; ICAR-CAZRI, Jodhpur; ICAR-NBFGR Regional Station Jodhpur; GBPUA&T, Pantnagar, Nainital; HARP, Ranchi and TNAU, Arrupokattai. Rai and Dwivedi (1992) and Vishal Nath et al. (2003) reported wide range of bael genetic diversity in Northern and Eastern-Central India (Fig 2). Apart from tree morphological characters, wide variability exists in fruit shape, size, bearing habit, pulp colour, texture, fiber content, sugar content, mucilage content etc., in different genotypes. Some types have more number of seeds, gum locules and thick pericarp. These can be considered as inferior types. However, some good selections have been made at NDUA&T, Kumarganj, Ayodhya; GBPUA&T, Pantnagar, Nainital and ICAR-CIAH, Bikaner, which are now becoming popular for commercial cultivation. At ICAR-CISH, Lucknow, collection and evaluation of bael germplasm was done resulting into identification of two promising selections i.e.; CISH-B-1 and CISH-B-2. Besides this, some germplasm were also collected and maintained in the field gene bank at ICAR-CAZRI, Jodhpur and NDUA&T, Faizabad.

Table 4. Bael cultivars released in India

Cultivar	Organization from where released
Narendra Bael – 5	NDUA&T, Kumarganj, Ayodya
Narendra Bael - 7	NDUA&T, Kumarganj, Ayodya
Narendra Bael - 9	NDUA&T, Kumarganj, Ayodya

Narendra Bael - 16	NDUA&T, Kumarganj, Ayodya
Narendra Bael – 17	NDUA&T, Kumarganj, Ayodya
Pant Aparna	GBPUA&T, Pant Nagar, Nainital
Pant Urvashi	GBPUA&T, Pant Nagar, Nainital
Pant Shivani	GBPUA&T, Pant Nagar, Nainital
Pant Sujata	GBPUA&T, Pant Nagar, Nainital
CISH-B-1	ICAR-CISH, Lucknow
CISH-B-2	ICAR-CISH, Lucknow
Dhara Road	ICAR-CAZRI, Jodhpur
Goma Yashi	CHES (CIAH), Godhra
Seedling selections with desired fruit (Thin shell, less seed, fibre and mucilage, high TSS content)	HARP, Ranchi; HETC, Basti; BAC, Sabour; MPUA&T, Udaipur; CSAUAT, Kanpur and OUAT, Bhubaneswar

Fig.2. Biodiversity in *Bael*

Among the existing biodiversity of bael in India it can be grouped into two prominent types i.e., one small fruit type, having bitter pulp with more seeds, mucilage and fiber content and second of large fruit type with thin shell, less seed, fibre and mucilage and more sweet pulp. The earlier type is generally used for medicine preparation purpose, because of high marmelosin and psoralen content, while the second type is generally used as dessert fruit and for preparation of processed products viz., Sherbat.

Conservation of bael genetic resources is being undertaken at various field gene banks of ICAR Institute and State Agricultural Universities. Good number of collection is being maintained at CCSHAU, Regional Station, Bawal, Rewari (10 collections), NDUA&T, Kumarganj, Ayodya (24 collections), ICAR-CIAH, Bikaner (16 collections), ICAR-CISH, Lucknow

(36 collections), GBPUA&T, Pantnagar (10 collections) and ICAR-CAZRI, Jodhpur (5 collections).

Varieties

Standard cultivars of bael were not known earlier. Only some locally cultivated types like Mirzapuri, Kagzi Gonda, Kagzi Etawah, Darogaji and Rampuri were cultivated by the farmers of the area. Recently, some new varieties with good attributes, such as dwarf tree with medium fruit size (1.0-1.5 kg), less fiber and seed content, high TSS, thin shell, less mucilage, pleasant flavour with acceptable aroma, less prone to fruit drop and cracking and less attack of diseases and pests have been identified and advocated for cultivation from different research institutes and SAUs. Some of the promising selections were made at NDUA&T, Faizabad, GBPUA&T, Pantnagar, CHES, Godhara and ICAR-CISH, Lucknow are described as under.

Narendra Bael-5 (NB-5)

Plants have precocious bearing and are of medium height (3-5 m) with spreading canopy. Fruits are round with flattened ends, medium in size (21×25 cm) with an average weight of 900-1000 g. Pulp with low mucilage, seeds, fiber content and soft with excellent taste and sugar (35-38°B, TSS). The average fruit yield of a full grown tree ranges from 50-60 kg (Fig. 3a, b, c).

Fig. 3a. NB-5 fruit on tree, 3b. NB-5 harvested fruits, 3c. NB-5 cut fruit

Narendra Bael-7 (NB-7)

Plants are of medium height (5-7 m) and less spreading type. Fruits are round with flattened ends (17.5×74.0 cm) weighing around 3.0-4.5 kg. The fruits have moderate number of seeds and less fiber with moderate TSS (27-30°B). The average fruit yield of a fully grown tree ranges between 70-80 kg (Fig 4).

Fig.4. NB-7

Narendra Bael-9 (NB-9)

Plants are of medium height (4-6 m) with spreading nature. Fruits are medium in size (26×33 cm) and oblong round with smooth surface having high TSS (35-40°B). The fruit contains medium quantity of mucilage, moderate fiber, mild fragrance, sweet taste, mild acidity, soft orange yellow pulp, thin shell with less seed content. An average yield of 70-80 kg is obtained from a fully grown tree (Fig 5).

Fig. 5. NB-9

Narendra Bael-16 (NB-16)

Tree erect type with semi compact foliage, trunk colour blackish grey with splitting of bark in irregular manner, leaf medium sized, lanceolate, colour green with smooth surface along with wavy margin, tree possess very few thorn of medium size, fruit weight (0.86 kg), pulp : fruit weight ratio (0.77), TSS (35°B) with medium seed content (131 seeds/fruit) (Fig. 6).

Fig. 6. NB-16 fruits

Narendra Bael-17 (NB-17)

Tree spreading type with semi compact foliage, trunk colour grey with splitting of bark in rectangular manner, leaf medium sized, lanceolate, colour green with smooth surface, non-wavy margin. Tree posing very few thorn of medium size, fruit weight (1.97 kg), pulp : fruit ratio (0.76), TSS (36.5°B) with medium seed content (103 seeds/fruit) (Fig. 7).

Fig. 7. NB-17 fruits

Pant Shivani

It is a mid season variety. Trees are tall, vigorous, dense, upright growing, precocious and heavy bearer. Fruit shape is ovoid oblong (49.7×49.2 cm) with average fruit weight ranging between 1.2-2.0 kg (Fig 8). Shell is medium thin and pulp is lemon yellow in colour with pleasant flavour and less mucilage. Seed number and fiber content are low to medium. Pulp content is high (69%) with good taste having TSS 34-35°B, acidity 1.31 per cent and ascorbic acid 15 mg per 100 g pulp (Fig. 8). Storage quality of the fruit is good. The fruit yield is from 50-60 kg per tree.

Fig. 8. Pant Shivani fruits

Pant Aparna

Trees are dwarf with drooping sparse foliage and are almost thornless, precocious and heavy bearer. Leaves are large, dark green and pear shaped. Fruits are globose with average size (35.6×36.6 cm) and weight 600-800 g (Fig 9a.b). Fruit pulp is yellow and rind is thin. Fruits have about 46 per cent pulp with good TSS (34°B), acidity (0.8%) and ascorbic acid (15 mg per 100 g pulp). Mucilage, seeds and fiber contents are low. Mucilage and seeds are enclosed in separate pockets (Fig. 9c). Flavour and taste of fruit is very pleasant. The cultivar is ideally suited for processing. The average fruit yield is 30-40 kg per tree.

Fig. 9a Pant Aparna fruit on tree, 9b. Pant Aparna fruits, 9c. Pant Aparna cut fruit

Pant Urvashi

It is a mid season variety. Trees are tall, vigorous, dense, upright growing and precocious. Fruit is ovoid oblong (47×49 cm) and weighing around 1.6 kg. Fruit shell is medium thin and lemon yellow in colour. Pulp is bright yellow with pleasant flavour. Number of seeds and mucilage content are medium and fiber is low. The fruit contains about 68 per cent pulp having 32°B TSS, 1.15 per cent acidity and 12.6 mg per 100 g pulp ascorbic acid. The average fruit yield is 27-30 kg per plant.

Fig. 10. Pant Urvashi fruits on tree

Pant Sujata

It is a mid season variety. Trees are medium dwarf with drooping and sparse foliage, dense, precocious and heavy bearer. Fruits are globe shaped, depressed at both ends having an average size 48.0×50.4 cm and weight 1.14 kg. Fruit shell is thin and light yellow in colour, when ripe. Pulp is light yellow, number of seeds is less and mucilage and fiber contents are low. The fruit flavour is pleasant. The fruit contains about 77.8 per cent pulp, 30°B TSS, 0.75 per cent acidity and 18 mg per 100 g pulp ascorbic acid. The average fruit yield per tree 45-50 kg.

CISH B-1

It is a selection from open pollinated seedlings. It is a mid season variety which matures during April-May. Trees are tall with vigorous growth and dense canopy and have erect growth habit, precocious and heavy bearer (12a). Fruit shape is oval to oblong and fruit size is 15-17.8 cm in length and 39.2-41.0 cm in circumference (12b). Average fruit weight is about 1.01 kg. Fruit shell is thin (0.12-0.15 cm thickness), pulp is dark yellow with pleasant flavour and less mucilage content (12c). Seed content is less (35-40 seeds per fruit) with low seed to pulp ratio 1 : 206 and 65.57 per cent pulp. The colour of fruit turns to lemon yellow upon ripening (12d). It has very good taste and flavour. TSS of fruit is high (38.0°B) with total carotenoids (1.18 mg per 100 g pulp), total sugars (20.54 %) and tannins (3.5 %) and is good for processing. The yield of a fully grown tree is around 50-80 kg.

Fig. 12a, b CISH B-1 fruiting on tree, 12c CISH B-1 harvested fruit, 12d cut fruit

CISH B-2

It is also a selection from open pollinated seedlings. Tree is dwarf with medium spreading habit. Foliage is sparse and almost thorn less, precocious with moderate bearing habit. Fruit is oblong to round in shape with average length of 14.80 cm and a circumference of 52.64 cm. Average weights of the fruit is about 2.25 kg (Fig.13). Fruit pulp is orange yellow and shell is thin (0.24-0.26 cm). Seed and fiber contents are low with an average seed number of 50.12 per fruit and low seed to pulp ratio (1 : 270) and 61.32 per cent pulp (Fig.13). It has good taste with pleasant aroma. The fruit has TSS of 31.9°B, 0.99 mg per 100 g pulp of total carotenoids, 16.33 per cent total sugars and 2.45 per cent tannins. The yield of a grown up plant is 60-90 kg.

Fig. 13. CISH B-2 fruits

Goma Yashi

It is early maturing variety. Plants are semi-spreading, small with relatively low stature. Leaves with drooping growth habit, less lateral branch growth (20-35 cm annually), central leaf size is 13.2×6.7 cm, lateral leaf size is 9.2×5.3 cm and ovate having acute apex. Budded plants flower in 3 years. The tree flowers during last week of April to last week of June. Average fruit size is about 13 cm in length and 12.5 cm in breadth and 41-45 cm in circumference with weight of 0.1-1.6 kg (Fig. 11). Shell thickness is thin with 0.17 cm and weight is 180-210 g. Seed weight is 25-30 g and average fiber weight is 40.24-51.2 g. Locules in cross-section is 13-15. TSS is high with 35-39°B, acidity 0.2-0.32 per cent and ascorbic acid 22 mg per 100 g of pulp. It is highly suitable for high density planting.

Fig. 11. Goma Yashi fruits

Thar Divya

Thar Divya, an early-maturing variety of bael for dry land, was released from ICAR-Central Horticultural Experiment Station, Vejalpur, Godhra during 2015. This selection was collected from Badalpatti village, Badalapur Block, Jaunpur District, Uttar Pradesh during 2006. Trees have vigorous and dense canopy, less spines, prolific-bearer, less fruit sunscald, drought resistant and hardy variety. It is a tall tree relatively upright growth having deliquescent branching habit. Tree height (5.98 m), stem girth (46.62 cm) and plant spread (5.64×5.48 m) at 9 years age.

Fruits attain maximum size up to September. Variety is early maturing (February), ripe after 270 days of fruit setting with an average yield of 70-80 kg/tree during 9th year under rained hot semi-arid conditions in western India. Their fruits shapes are oblong elliptical and colour, dark green, greenish yellow and yellowish green, respectively in different stages of maturity (Fig. 14a). Fruits have thin rind, less seed, high pulp with fine fibre, high TSS, less acidity, uniform ripening with excellent dark yellow colour of pulp. It is highly suitable for powder and sharbat making. Its fruits are of 1.32 to 2.37 kg size. Fully mature fruits can be kept for 10-15 days (Fig. 14b).

Fig. 14(a) Thar Divya bearing trees (b) Thar Divya – ripe fruits

Thar Neelkanth

Thar Neelkanth has vigorous and lustrous growth with dense canopy. It is drought hardy and prolific-bearer variety. It start bearing in third year and ripening after 320 days of fruit setting with an average yield of 75.67 kg/tree during eight year under rainfed hot sami-arid conditions. Fruits are rich in fine fibres (4.88 %), with thin rind (1.8 mm), high pulp content (71.30%) and with less acidity (0.29%), less number of seeds (83.21 mm) and mucilage and high in TSS of pulp (41.20 °B) and TSS and acidity ratio (142.07). It is highly suitable to grow under fragile agro-climatic conditions.

Propagation

Traditionally bael was propagated by seed. However, there is an inherent limitation associated with the seedling progenies and generally they are not true to type and hence, seed propagation is limited for the raising of rootstock only.

Seed propagation

For raising seedlings, freshly extracted seeds from healthy fruits should be obtained and sown immediately. Since, bael belongs to recalcitrant category, the seeds cannot be stored for longer periods under normal storage conditions. Studies conducted at ICAR-NBPGR, Pusa, New Delhi showed that freshly harvested seeds of diverse accessions showed germination from 60-100 per cent with moisture content ranging from 12-20 per cent.

To prevent the losses due to 'damping off' at nursery stage, seed treatment is essential. Seed treatment with available suitable fungicide @ 1 g/100 g of seed or *Trichoderma viride* @ 4g/kg of seed can be used effectively.

Raising of seedlings in nursery beds

Bael seeds have shown no dormancy and germinate 10-15 days after sowing. Generally, the freshly extracted seeds are used for sowing, however, if required these can be stored up to 132 days with proper treatment. For storage, after extraction, seeds treated with fungicide WP formulation @ 1 g/ 100 g is required and stored in alkathene bags at room temperature. For nursery raising after fungicidal treatment seeds can be sown in 2 cm depth in the nursery within 10-15 days of extraction. Seeds should not sown deep, as seedling emergence may be delayed and there is chance of mortality due to poor aeration. Seed can also be shown in polythene bags, facilitates an easy handling of seedling and grafted saplings. Mixture of FYM, sand and soil (1:1:1) should be solarized and mixed before filling in polythene bags. When seedlings attain 10-15 cm height in nursery bed, these should be dug up along with earth ball and should be planted in separate nursery or poly bags. The shifting of bael seedlings is necessary to check the growth of tap root system and to encourage the fibrous / adventitious root development. The young growing seedlings protected from intense radiation and frost.

Raising rootstock in polythene bags

Rootstock growing in nursery beds and lifting of budded / grafted plants with earth ball is difficult and practically not feasible in light soils as the earth ball breaks and there is change of mortality of those plants. Again during transportation of these plants, there is high mortality of plants. Polythene bags are recommended for commercial scale raising of rootstocks

as it reduces the time for growing seedling and also offers protection to avoid damage during handling and transportation,. Generally, polythene bags of size 25×10 cm are used with holes made at the bottom and sides for proper drainage and aeration and filled with rooting medium. Normally, one to two freshly extracted seeds are shown in each bag and then kept in trenched bed / poly house so that it can be irrigated easily. Coiling of root is a problem in old seedlings for which root pruner is used for pruning of roots. Seedlings can also be raised in nursery beds in open or poly-house and transplanting of seedlings (2-4 leaf stage) in poly bags gives 80-90 per cent success.

Nearly 8-10 months old seedlings of pencil thickness are used as rootstock for budding / grafting. Plants grown in the polythene bags can be transported to distant places with higher survival success.

Rootstock raised in the field

For getting good survival and success under rain-fed/undulated soil conditions, sowing of seeds may be done directly in the field during monsoon (June-July) as per layout plan and the seedlings become ready for in situ budding or grafting during June - July, year after sowing. If there is long gap of two spell of rains, plants should be irrigated as and when required. Proper irrigation is required to save the plants in the field during summer. Since, no planting is involved in this case, the plants retain the deep roots and thus, become more hardly and vigorous. In the next year after sowing (June-August), different superior cultivars from selected mother plants should be grafted / budded.

Vegetative propagation

Through vegetative propagation, true to type plants can be prepared. Vegetatively propagated plants come into bearing earlier compared to the seedling trees (Fig 15). Generally in vegetatively propagated plants, fruiting starts from fifth year and full bearing potential is attained in 10-15 years.

Fig. 15. Vegetative propagation of Bael seedlings

Selection of mother plant

Selection of the elite mother plants should be done with greatest care. For selecting mother plants of bael, following basic characteristics needs to be considered,

(i) Plants should be consistently high yielding.
(ii) Quality of fruit should be very good with all desired traits.
(iii) Plant should be free from diseases and pests.
(iv) It should be in full bearing stage.

Budding

Bael can also be propagated successfully by budding on 1 or 2 year old rootstocks. Different methods of budding viz., patch, shield, forket, ring and modified ring budding were tried with varying success percentage. Generally patch budding is very common and mid of May to July is the most congenial period for getting higher percentage of success of budding under field conditions. In patch budding method, a plumpy and healthy bud is marked from the axil of leaf. Leaf blade is removed with the help of a sharp knife leaving petiole intact. The upper cut is given in about 1.0-1.5 cm above bud, which goes downwards upto 1.0-1.5 cm below the bud without wood portion and then lower cut is given about 1 cm below the bud making a rectangular patch having bud portion in the centre place of the patch. Similar rectangular incision (patch) is cut on the seedling rootstock by placing the bud on the rootstock to make the exact size of the bud on them and after removing the bark of root stock, the bud is placed at the juncture. The bud is pressed by hand to remove the open space (air). Hence, bud come in close contact with the wood of root stock and tied tightly except the place of bud eye with polythene strip (200 gauge thickness and 2.0-2.5 cm wide). Sometimes, the cuts on rootstocks are wider, at least one side bark of scion (bud) and stock must be matched properly. The rootstock is cut about 10-12 cm above the graft to facilitate early bud sprout. After union, top of the rootstock is cut a little above the bud union and polythene strip is removed carefully.

Maximum success of budding in bael is obtained when average monthly temperature ranges between 29-34°C and relative humidity ranges between 60-70 per cent during the time of budding.

Preparation of scion for budding

The shoots from selected mother tree should be defoliated 8 days prior to anticipated budding date. The defoliation enforces proper development of axillary buds.

Preparation of rootstock for budding

One year old seedlings of desi bael should be used as rootstocks. These seedlings can be grown in raised nursery beds or in poly bags. In problematic areas, seedling rootstocks should be raised in situ. For this 3-4 seeds should be sown per pit for germination and after germination healthy and stout seedlings should be used as rootstock and remaining ones be removed.

Precaution in budding

Success per cent in budding increases if following precautions are taken

The contact between stock and scion should be very fine and there should not be any gap between them as it adversely affects the budding success.

The bud union should be properly tied with polythene band, so that rain or rain water do not enter the gap. Rains play a negative role and create physical hindrance through seeping the water in between stock and scion and there by hamper the perfect union.

Softwood grafting

Softwood grafting is generally performed in the form of wedge or tongue grafting. Pencil thickness seedlings are preferred for grafting purpose. The top portion of root stock is cut off at the height of 15 - 20 cm from the surface of poly bag or ground. Splitting the beheaded rootstock vertically down the centre, to a point 4 to 5 cm below the cut surface. Scion shoots are collected from selected variety. About 18-20 cm long mature shoots (2-4 months old) are defoliated 10-12 days prior to grafting operation. These scion shoots are detached from the mother plant with the help of sharp secateurs. Scion stick should be cut from both sides into a tapering wedge approximately 4 to 5 cm long. The tapered end is inserted into the split stem of the rootstock of the same size. The rootstock and scion are wrapped firmly with 2 cm wide and 25-30 cm in length polythene strip (Fig 16). Immediately after grafting, the scion is covered with poly cap. After 15-20 days of grafting scion shoots sprouts, which can be seen from outside also. The poly caps are carefully removed after 25-30 days and these are kept for hardening. Early removal of poly cap results in high mortality. Generally winter months are suitable for wedge grafting, whereas in case of bael maximum success is obtained in the month of April-May, since bael defoliate all leaf during these period. In green house conditions, year round grafting can be done. Field transferable grafts can be ready within 10 - 12 months after seed sowing. This method ensures 90-100 per cent

establishment and survival of transplants in the field due to undisturbed shoot system.

Fig. 16. Softwood grafting

Bud wood storage on graft success

Scion shoots wrapped with newspaper followed by moist jute cloth can be used for grafting up to the 4th day from the date of detachment from the mother plant successfully.

Care of nursery plants

Bael seedlings at nursery stage are damaged by frost during winter and by scorching hot desiccating wind during summer months under north Indian conditions. Hence, nursery beds should be kept under thatched shade or shade net, etc. These beds should be regularly irrigated, to avoid of frost damage. During summer, irrigation should be given at 2-4 days intervals depending upon the climatic conditions. The nursery beds/poly bags maintain weed free regular weeding/ hoeing. Spray of GA_3 (1000 ppm) enhance seedling growth like height, number of branches, secondary root, dry weight of leaf stem and top growth.

Top working

Old and uneconomic bael trees can be turned into economic and vigorous one by top working. In this method, the trees are headed back from 1.0 to 1.5 m above the ground level (from where a main scaffold branch arises) during the month of February-March and new shoots emerge from the cut stumps. Only four to six healthy shoots emerging from all the four directions are allowed to grow. Patch budding/ cleft grafting on these shoots should be performed with improved commercial scion cultivar in the following June-July months. These trees start fruiting in three to four

years and attain full bearing in about 8-10 years. In this way, inferior, old and unproductive bael trees can be transformed into superior fruit trees (Jauhari and Singh, 1971).

Agro-techniques

Planting

The planting of bael is done at 10×10 m or 8×8 m depending upon the need, soil fertility and agro-climatic conditions. Pit of one cubic meter size are dug two months prior to planting and kept open for solarization. Later, in each pit 3-4 baskets (25-30 kg) of well rotten FYM and 50-100 g methyl parathion dust (2%) is mixed with top 50 per cent soil and filled. In sodic soil, 5-8 kg gypsum (as per requirement) along with 20 kg sand is also incorporated. These filled pits are irrigated and left for month to complete the soil reaction. In sodic soil, the rain water should be allowed to collect in the pit, which should be flushed twice or thrice to remove the harmful salts from the pit to facilitate better establishment. The filled pits are irrigated thoroughly, if there are no rains to settle down. After the soil becomes workable, the grafted/budded plants are planted in the center of the pit. After planting irrigation should be given immediately.

The ideal time of planting is July-August, however, if irrigation facilities are assured, it can be planted during February-March also. In dry land or arid region, in situ planting was found suitable for orchard establishment.

Shelter belts and windbreaks around the orchard protect the trees from hot and desiccating winds during summer and cool waves during winter. For this purpose two-three fast growing drought hardy tree species (Akash neem, Gonda, Boradi, Eucalyptus, etc.) can be planted in staggered manner. Newly planted samplings can be protected from hot and cool winds by close hedge/strip of fast growing plants like dhaincha and Castor. Precaution must be taken to protect the newly planted plants from frost damage.

Planting system

Generally, bael plantation is done in square system of planting (Fig. 18). In most of the cases, seedling bael plantation is done on boundary of orchards as a wind break. In an organized orchard, planting of bael is done at 6×6 m in square system and 5×7 m in rectangular system (Singh and Vishal Nath, 1999). The main objective of a particular planting system is to accommodate more number of plants per unit area, without adverse effect on yield and fruit quality. In India, farmers are poor and have less resource like land holding, irrigation facility, etc., high density planting is

the right choice increase the productivity by accommodating more number of plants per unit area.

Fig. 18. Organized Bael orchard

Irrigation and weeding

Bael plants are hardy in nature and hence, once established, it can withstand drought conditions, however, new and young plants need to be watered at frequent intervals. During dry summer period, bael trees shed their all leaves, hence, their water requirement is reduced due to its dormant phase. During this period only one or two irrigation is sufficient. In juvenile phase, trees require 8-10 irrigations in a year, while bearing tree require 2-3 irrigation during the time of fruit growth and development. Drip system of irrigation can be adopted to supply the optimum quantity of water to the plant and save the valuable water from wastage, thereby, increasing the water use efficiency. Full grown up bael tree (> 10 years) can successfully be grown without irrigation under rain-fed conditions. Apart from irrigation, time to time basin of tree should be cleaned by weeding and hoeing.

Mulching

Mulching with organic waste has been found very effective for establishment of bael orchard in sodic and ravenous waste land. Mulches conserve and retain soil moisture but also exert beneficial effect like suppression of extreme fluctuation of soil temperature, reduced water loss through evaporation, maintenance of soil fertility, suppression of weed growth and, thereby improve plant growth and yield. Regular uses of organic mulches are also helpful in improving physico-chemical properties of soil, beneficial microbial population and soil aeration. Under rain fed conditions, putting organic mulches in the tree basin is beneficial

for successful bael cultivation as organic mulch itself disintegrate in soil and improves fertility. Among the different mulch materials, paddy straw and sugarcane trash show better response. Mulching with these waste materials over many years is helpful in improving organic matter content, infiltration rate, reducing pH and EC content of soil and also restricting the upward movement of the soluble salt and thus, escaping their toxicity menaces in the salt affected soil. Mulches should be placed in the tree basin (20 cm thick) after rainy season and un-decomposed organic mulch should be incorporated and mixed with soil of tree basin in forthcoming monsoon. Leaf litter of bael tree under the canopy is not only effective to conserve soil moisture during summer but also improve the soil properties. Among inorganic mulches, black polythene is generally found better.

Nutrient management

For obtaining good growth, yield and quality production, manure and fertilizer application should be done judiciously. In soil application, fertilizer should be placed in active root zone (one meter away from the tree trunk and beneath the canopy). The fertilizer and manure should be incorporated properly (in surface soil, 10-15 cm deep). With the advent of drip irrigation and availability of liquid fertilizer, the fertigation technology is considered to be the efficient. Being minor or neglected crop, not much work has been done on manure and fertilizer requirement. Normally 5 kg FYM, 50 g N, 25 g P and 50 g K per plant should be applied to one year old bael plant. This dose should be increased every year in the same proportion upto the age of 10 years. Thereafter, a constant dose of 500 g N, 250 g P and 500 g K along with 50 g FYM should be applied above 10 year old plant. In sodic soil, plants generally show zinc deficiency symptom, for which 250 g zinc sulphate per plant along with fertilizer application is recommended. Beside this, foliar application of 0.5 per cent zinc sulphate in July, October and December is recommended. Full doses of manure and fertilizers should be applied in the month of June-July. In some bael orchards, where fruit cracking is a problem, 100 g borax per tree should also be applied along with manure and fertilizers. After manure and fertilizer application, light irrigation is recommended. Some times in more fertile soils, the tree have tendency to put forth on more vegetative growth with the result that the fruiting is reduced/delayed. In these conditions, additional fertilizer should not be applied.

Training, pruning and weed management

Young bael plants are trained with the help of stakes, so that they grow erect. In order to develop good framework, it is essential not to allow lateral branches up to 75 cm from the ground level. Afterwards, 4-6 branches

emerging from different directions should be encouraged to grow. Suckers appearing from rootstock should be removed regularly. Generally, bael does not require pruning once the tree start fruiting, because the branches of bael tree is self-oriented, however, in case of rosette growth, few branches should be headed back from its place of origin to have a well spread scaffold branches. Regular pruning in bael plants are not required, because fruiting takes place on one year older shoots. The trees are allowed to grow as such but dried, criss-cross branches, weak, diseased and broken twigs should be removed from time to time preferably after fruit harvest and before the commencement of new growth.

In nursery weed management is necessary. When seedlings grow, weeding should be done at reasonable interval for the proper and healthy growth of the seedlings. In initial years of planting also, weeding is required for proper growth of the plants. In the orchard, hoeing, hand weeding and ploughing of the soil, twice or thrice in a year are required to maintain good tree growth.

Intercropping

Intercropping is headed to maximize the land use efficiency for generating additional income particularly during the initial unproductive phase of orchard. The interspace should be utilized by growing suitable intercrops. For that the leguminous crop like pea, cowpea, black gram, green gram and guar and vegetable like brinjal, tomato, spinach, coriander, chilli, garlic, etc, can be grown. The crops having high water requirement should be avoided as intercrops, since bael is highly susceptible to water logging. In bael orchards under salt affected or marginal soil conditions, it is advisable to grow green manure crops like dhaincha (Sesbania sp.) for few years to improve the physico-chemical properties of the soil.

Canopy management

Canopy management in bael needs to be done to maintain proper structure (shape and size) of the plants and to increase productivity and quality of the fruits. Hence, the annual pruning is done to improve and regulate tree size and shape to achieve the desired architecture and also reduce the foliage density by removing the unwanted branches of the tree for better penetration of light and subsequent production.

Flowering and fruiting

The budded/grafted bael trees start flowering after 4-5 years of planting, while seedling trees flower 7-8 years after planting. Flowering starts with the commencement of new growth in the month of May-June.

Fruit setting takes place by the end of May and continues upto July. Fruiting occurs on one year old shoots. The complete fruit development (ready for harvest) takes about 10-11 months. Hence, by next April-May, fruits are ready for harvest. However, the fruit maturity varies according to the genotype and agro-climatic conditions.

Fruit growth and development

The fruit growth and development of bael follows a single sigmoid curve. The growth rate of the fruit has three district phases i.e., the initial slow phase for one month, followed by rapid increase for three months and then more or less stationary phase till the fruits are matured. The moisture content decreases during later part of ripening of fruits. With the decrease in moisture in bael, the hardness of starch appears and increases steadily till harvest but disappears with ripening.

Insect-pest and disease management

Lemon butterfly (*Papiliodemolious L.*)

To manage lemon butterfly, hand-picking of various stages of the pest and their destruction has been suggested. This is very useful in mitigating the pest problem especially in nurseries and new orchards. In case of severe infestation, spray with Lambda Cyhalothrin @ 0.10% is recommended. Spraying of Bacillus thuringiensis (Bt) was found effective against grownup caterpillars.

Leaf miner (*Phyllocnistiscitrella Stainton*)

The caterpillars attack only young and tender leaves. The larvae make serpentine mines in the leaves feeding on epidermal cells of the leaves leaving behind the remaining leaf tissues quite intact. The mining larvae feed actually more on sap than on solid tissues of the leaf. The mined leaves turn pale, get distorted and may dry up. The pest occurrence has been observed around the year except December to February months.

As the larvae are inside the mines, these cannot be killed easily by insecticidal applications. For effective control, affected parts during winter should be pruned heavily and burnt. Spraying with neem cake extract @ 0.25 per cent keeps the infestation under check. Spray of Lambda Cyhalothrin @ 0.10% at bud stage once or twice if 30 per cent leaves showing infestation is effective.

Bark eating caterpillar (*Indarbela* spp.)

Bark eating caterpillar is a polyphagous insect pest, has been found damaging many fruit crops, avenue trees and ornamental trees. This

pest causes considerable damage to the fruit crops, like guava, mango, citrus, orange, jamun, litchi, aonla, jack fruit, pomegranate etc, including forest trees. The incidence of this pest could be noticed by the presence of elongated zigzag ribbon-like messy web or galleries made by fragments of bark pieces and excreta with silk, near the fork or angles of the stem or branches. The female moths lay eggs in clusters of 15-20 directly on the bark of branch. The freshly laid eggs were pale colored and oval in shape and became creamy white after sometime. Pupation takes place in the tunnel in the wood; the pupa possesses rows of teeth or hooks on the abdominal segments by means of which it climbs out of the larval tunnel to release the mouth. The pupal period lasts about 3 weeks. Larva bores a short tunnel downwards in to the wood, usually at the junction of a dead branch or snag and the hole. The full grown larva is 38 to 50 mm long, smooth skinned with dark chitinized patches on the segments. The larva bores into the trunk or branches, usually at forks or angles, to a depth of 15-25 cm. This tunnel is the refuge of the larva during the day (and later for pupation); at night it emerges from the tunnel and eats the bark of the tree in the immediate vicinity of the hole. Small trees are easily ring-barked by this pest and die. If enough bark is eaten away, even large trees are disturbed by the interrupted sap flow; they may fail to flush and drying of the branches occurs. Large dark brown webby masses, comprising chewed wooden particles and faecal matter, are conspicuously seen plastered loosely on tree trunks or main branches, especially near the forks.

It can be managed by:

* Orchard should be kept clean and healthy.
* Pest larvae should be removed by inserting iron spoke in holes at early stages of infestation and can be killed using any contact insecticide.
* Bark eating caterpillar on Aonla can be managed by inserting cotton wool soaked in Lambda Cyhalothrin (0.25 – 0.5%) in the borer hole and block it with the mud.
* Entomopathogenic fungus, Beauveria bassiana natural epizootic was found in the field it can be exploited for better management of the pest.

Spiralling whitefly (*AleurodicusDispersus* Russel)

Spiralling whitefly is a polyphagous pest with a characteristic spiralling pattern of oviposition on the underside of leaves. Eggs are laid on lower surface of the leaves. The pest has three larval instars and fourth forms the pseudopupa. Life cycle is completed within 21 to 48 days. Nymphs and adults suck sap from leaves leading secretion of honey dew, which

causes the growth of sooty mould. In severe cases it leads to defoliation and reduction in flowering and fruiting.

Management

* Orchard hygiene and exclusion of weed host.
* Setting up of yellow sticky traps @ 20 ha^{-1} to attract adults
* Conserving coccinellid predators like , Cryptolaemus montrouzieri in orchards.
* Some parasites, Encarsia haitensis Dozier and E. guadeloupae Viggiani found efficient against spiraling white fly, Which can be used for management of this pest.

Dieback

The disease is caused by Lasiodiplodia theobrome. Diseased trees suffer from drying of twigs from top to downward (Fig. 18). Brown spots appear on twigs and leaves and finally leaves drop. It can be managed by removal of diseased twigs followed by two sprays of Copper oxychloride @ 3 g/l at an interval of 15 days. Post treatment care for balanced nutrition and irrigation is necessary better recovery.

Fig. 18. Dieback of bael

Alternaria leaf spot [*Alternaria alternata* (Fr.) Keissler.]

Typical concentric rings are formed in spots/ lesions of brown colour on leaves (Fig. 20). The size and shape of lesions mostly remain irregular and under severe conditions they coalesce and symptom looks like blight. Severe defoliation may take place, if not managed at right time. The disease is equally severe on seedlings and trees (Madaan and Gupta, 1985). High humidity must be avoided in shade net houses and precautionary spray on seedlings, grafts and trees should be done with copper oxychloride

(0.2%) or hexaconazole (0.1%) at 15-20 day interval during monsoon and heavy dew periods.

Fig. 20. Alternaria leaf spot

Black leaf spot [*Isaropsis* sp.]

Isaropsis sp. Is the cause of this disease, which develops on both the surfaces of leaves as 2-3 mm black spot (Fig 21). For management of the disease, spraying of hexaconazole (0.1%) is recommended.

Fig. 21. Isaropsis black leaf spot

Bacterial shot hole and fruit canker [*Xanthomonasbilvae*]

Patel et al. (1953) first time reported the incidence of this disease in Maharashtra state. The disease may appear in the form of water soaked tiny round spots with typical yellow halo around. The spots gradually enlarge and depression or shot hole develops in the center. Infected fruits show symptoms of water soaked lesions, larger in size, raised, rough and irregular in shape. Later, fruit lesions become hard and brown. For control of the disease, fortnightly spray of Streptocyline (200 ppm in water) is recommended.

Stalk end rot [*Fusarium solani* (Mart.) Sacc., *F. semitectum* var. *majus*]

Stalk end rot of bael is caused by Fusarium solani (Mart.) Sacc. The dropping of immature young fruits takes place due to the infection stem end portion. Fungal attack on the peduncle ends of the fruit, forms a dark brown lesion (Fig. 22 a,b). Later, the fungus weakens the peduncle of the fruits resulting into fruit drop (Misra, and Srivastava, 2003). The rind near stalk and underlying flesh softens and become dark brown in colour (Fig. 22 c). Morphology of fruits is not affected by the disease. Affected fruits may fall down with a little jerk of wind.

The disease can be managed by spray with propiconazole or hexaconazole @ 1.0 ml/l at fortnightly interval when fruits are small.

Fig. 21 (a) Reproduction of symptom (b) Stalk end rot (c) Stalk end rot

Aspergillus rot [*Aspergillus awamori* Nakazawa]

Soon after harvest, fruits are prone to rot under storage if they are kept under ambient conditions. The high temperature favours infection and infected portion looks pale to dark coloured (Arya et al.,1986). In such fruit, Aspergillus develops and pulp becomes soft and emits foul smell. In later stages, infected epicarp may become soft after rot. The flesh under infected portion becomes black after rotting. To avoid the disease, proper care should be taken during harvesting so that fruits do not fall on the ground and get cracked. Care should also be taken that fruits do not damage during handling and transportation.

Shell soft rot of bael (*Syncephalas* trumracemosum)

This is another post-harvest disease of mature fruits. The infected fruit gets rotten very quickly and infected portion may have an easily removable layer on epicarp (Fig. 23a). Rotting of pulp is also observed under the infected epicarp. It becomes black with rotting (Fig. 23b). Rotten fruits omit foul smell (Misraet al., 2016).

Fruits should be harvested carefully so that it is not damaged during harvesting and transportation. The fruit may be dipped after harvest in hot water at 52±l° C and then dried in shade.

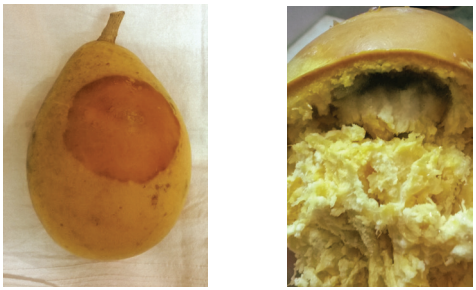

Fig. 23 (a) Shell soft rot (external symptom) (b) Shell soft rot (internal rot)

Physiological disorders

Fruit cracking

Cracking of fruits is a major problem in most of the areas in Uttar Pradesh. It has been correlated with soil moisture availability, as severe cracking has been recorded under dry conditions. The fruits may suffer from cracking during winter as well as during summer. Thus, to minimize this disorder agro-forestry may help in contributing different micro climate and proper care to maintain soil moisture throughout is also necessary. Number of irrigations may be reduced by adopting moisture conserving measures like mulching. Mulching with polythene or organic matter is very useful in rain-fed areas. Sometimes due to boron deficiency the cracking of fruit takes place in these case 100 g borax per tree should be applied along with fertilizer.

Fruit drop

Fruit drop in bael is a natural phenomenon, but sometimes its extent causes great concern. Fruit drop starts from July and continue till harvest. The maximum fruit drop takes place during August-September (Fig. 23). No remedy to control fruit drop has been found yet. However, spray of borax (0.1%) is effective in reducing the fruit drop to some extent. Apart from that plant growth regulators like planofix (2 ml/5 l of water) at pea stage minimize fruit drop considerably. If fruit drop is due to Fusarium stalk infection, hexaconazole @ 1 ml/l may be sprayed at 15 days interval.

Fig. 25 Fruit drop

Harvesting & Ripening

Bael fruits are ready for harvest during April-May, when the fruit shell changes its colour from deep green to yellowish green. At this time, the tree is in leafless condition and the fruits are completely exposed. Harvesting by shaking the tree is discouraged as the fruit is likely to develop cracks on its brittle shell due to impact of strike against ground. A minor crack on shell may cause heavy spoilage due to fungal infections, during storage. The fruit should be individually handpicked to avoid falling on the ground. Since, the stem end of the fruit is prone to infection, hence harvesting along with a portion of stalk (approximately 2 cm) is desirable practice. The stalk gets automatically detached when the fruit is ripe, indicating completion of ripening. Fruit setting in bael takes place during late May and ripe fruits are available in the following April-May (11-12 months) under Lucknow conditions. However, this may vary in different agro climatic zones of the country.

Grading & Packaging

Bael fruits owing to variation in shapes and sizes, require proper grading. The de-shaped/small and cracked fruit should be discarded. Bigger sized and medium/small sized fruits, depending on the varieties should be separated. Not much work has been conducted on packaging of bael fruits. Generally these are packed in gunny bags, basket or wooden boxes and sometimes just laoded unpacked. However, it is essential that cushioning material i.e., straw, paper, saw dust, news paper liner, paper cuttings etc. are used for packaging bael fruits. Care should be taken that the fruit should not develop any cracks or damage during packing, transportation, marketing and storage.

Storage

The storage life of the fruits depends upon the stage of harvesting. Bael fruits can be stored for 10-15 days at normal temperature. The storage life of bael fruit could be increased from 2 weeks at temperature 30°C to 12 weeks at temperature 9°C and relative humidity 85-90 per cent.

Processing

Bael fruit is rich in medicinal and therapeutic properties and is widely used in Ayurvedic medicines for curing stomach ailments. It contains 31.8 per cent carbohydrate, 1.8 per cent protein, 0.3 per cent fat, 1.7 per cent minerals and 2.1 per cent fibre along with calcium, phosphorus, iron, riboflavin, vitamin-C and carotene. It also contains anti-oxidants, namely marmelosin and psoralen having high therapeutic value. Bael fruit is not popular as table fruit due to its hard shell, mucilaginous and highly fibrous

nature of pulp with numerous small embedded seeds. However, it is widely used since time immemorial for preparation of preserve from mature green fruits. Ripe bael fruit is commonly used for preparing drinkby mixing the pulp with water and sugar. Milk may also be added, if desired. A beverage is also made by combining bael pulp with that of tamarind. Recipes for preparation of some popular bael products are given below:

(A) Products made from mature but unripe bael fruits

Murraba (Preserve)

Materials:

Bael fruit	- 1 kg (600 g in pieces)
Sugar	- 750 g
Citric acid	- 2.4 g
Potassium metabisulphite (preservative)	- 600 mg

Method: Cut the mature bael fruit in 3/4 inch thick slices using fine cutter or saw. Remove the shell, mucilage and seeds from the slices. Boil the pieces in 0.2 per cent (1.2g/600ml) citric acid solution till they become soft. Remove the pieces from the water. Spread sugar and pieces layer by layer and leave the content for 24 hours. Next day, remove the pieces and concentrate the sugar solution up to 60°B. Add required quantity of citric acid and potassium metabisulphite. Dip the pieces in sugar syrup for overnight. Concentrate the syrup up to 72 °B and dip the pieces again. Repeat this process till TSS of the solution reaches 72°B. After preparing the preserve, fill it in the jar in 45:55 ratio of bael pieces and syrup, pack and store.

Candy

Materials:

Bael	- 1 kg
Sugar	- 750 g
Citric acid	- 2.4 g
Potassium metabisulphite (preservative)	- 600 mg

Method: During the method of preserve making, when TSS of sugar solution reaches 72°B, remove the pieces from the sugar syrup and rinse with lukewarm water (45-50°C) twice or thrice till surface sugar is washed

out. These pieces is dehydrated in solar or electric dehydrator at 60°C for 8 to 10 hours till the moisture content comes down to 10-15 per cent. Remove the candy from dehydrator and cool at normal temperature. Pack in the food grade plastic jar or pouches and store.

Powder (churan)

Materials:

Pieces of mature bael fruits	- 1 kg
Potassium metabisulphite (preservative)	- 1g

Method: Take mature bael fruits and remove the shell and seeds, etc. and cut into pieces. Mix preservative with the pieces and dry in electric dehydrator at 60°C for 7 hours. Grind the pieces and pass the powder through 80-100 mesh sieve. Pack the powder in food grade plastic containers or pouches and store.

(B) Products made from ripe bael fruits

Pulp

Materials:

Bael fruit	- 1 kg
Citric acid	- 3.5 g
Potassium metabisulphite (preservative)	- 2.4 g
Water)	- 600 mg

Method: Extract the pulp from mature ripe bael fruits. Mix with 0.2 per cent (1.2 g/600 g) citric acid along with water and boil till the pulp is separated from fibre. After cooling, pass this material through pulper and heat the filtered pulp up to 78-80°C. Mix the remaining portion of citric acid and potassium metabisulphite (dissolved in little amount of water) with the pulp properly. Fill the pulp in pre-sterilized jars and seal. Store the product at normal temperature.

Squash

Materials:

Bael pulp	- 1 kg
Sugar	- 1.15 kg
Citric acid	- 5 g
Water	- 300 ml

Method: Extract the pulp from bael fruits and preserve it as in case of bael pulp.Dissolve required sugar in lukewarm water and filter through muslin cloth to remove impurities. Mix sugar solution with bael pulp and heat up to 78-80°C. Add citric acid (dissolved in little amount of water). Fill the squash in pre-sterilized bottles and seal. Dilute with three times of chilled water for serving.

Ready to serve (RTS) drink

Materials:

Bael pulp	- 1 kg
Sugar	- 1.5 kg
Citric acid	- 20 g
Water	- 8.0 l

Method: Dissolve required amount of sugar in water and filter through muslin cloth to remove the impurities. Mix sugar solution with preserved bael pulp and heat up to 90°C. Add citric acid (dissolved in little amount of water). Fill the ready RTS drink in pre-sterilized glass bottles and seal. Keep the sealed bottles in boiling water for 20 minutes. Cool the bottles at room temperature and store at room temperature.

Jam

Materials:

Pulp	- 1.0 kg
Sugar	- 1.5 kg
Citric acid	- 11.0 g
Water	- 200 ml

Method: Mix required sugar in water and heat till it is completely dissolved. Filter it through muslin cloth to remove impurities. Mix the sugar syrup with preserved bael pulp and heat till TSS of the mixture reaches to 68°B. Dissolve citric acid in little amount of water and add to the mixture. Continue heating till end point (starts dropping as clots from spoon) is achieved. Fill the prepared jam in pre-sterilized jars, sealed with caps and stored at room temperature.

Toffee

Materials:

Pulp	- 1 kg
Sugar	- 400 g
Glucose	- 50 g
Milk powder	- 100 g
Butter	- 80 g
Potassium metabisulphite (preservative)	- 500 mg

Method: Heat the preserved bael pulp in stainless steel pan with regular stirring. When quantity of pulp is reduced to one third, mix sugar, glucose, milk powder and half quantity of butter and heat further. When end point (TSS 83°B) is achieved, add rest amount of butter. When toffee material is about to be ready, add preservative (dissolved in little amount of water). Spread the toffee material in 0.5 cm thick uniform layer in butter smeared trays. After cooling, cut the material in to toffee sized pieces and put them in electric dehydrator at 60°C. When moisture level comes down to 9-10 per cent, remove toffee from dehydrator, cool and wrap them in butter paper.

Marketing and economics

Bael fruits are mainly sold in domestic market exclusively for processing. Due to its hard outer shell, it can be transported to longer distances for marketing. Now-a-days, its demand is increasing in Ayurvedic system of medicines. It is used in many ayurvedic preparations and there is need to create more awareness about its medicinal attributes internationally to increase its demand globally.

Under north Indian conditions, a five year old tree of commercial variety NB-5 gives about 30-40 fruits per tree. The average weight of fruits is about 0.8-1.0 kg. With this level, yield is about 30-40 kg per tree. As per estimate from baelorcharding the net return is of about Rs. 1,00,000 per ha. There is good demand of baelproducts in the domestic market and one can fetch good income by establishing a small scale processing unit.

Future thrust

- Since, rich genetic diversity in bael germplasm is available in our country, particularly in the states of U.P., Bihar, Jharkhand, M.P., Orissa, Chhattisgarh, West Bengal, etc., proper attention is needed for selection of superior genotypes with good quality and high yield potential.
- Some of the major problems associated with bael are fruit drop, fruit cracking and rotting of fruits, for which identification of resistant/

tolerant genotypes and work for the management of pathogens involved with these problems is required.

- Development of cultivars with minimum seed and mucilage content is also very necessary.
- More emphasis on post-harvest technology should be given for value added and export oriented processed products.
- Promotion of small scale processing industries is a must to increase the processing.
- To increase the production of fruits in wasteland, screening of genotypes/cultivars is now essential for drought resistance, moisture stress and biotic stresses.
- Development of suitable varieties for high density orcharding.
- The medicinal properties of the fruit should be highlighted to global community to enhance awareness about this fruit.
- Research should be focused on bael based farming systems for proper land utilization.
- The traditional knowledge of bael needs to be protected through patents.
- Establishment of model nursery and availability of genuine planting material needs to be promoted.
- For achieving commercial cultivation of bael fruit, utilization of wasteland and orcharding in problem soils needs to be undertaken, as this crop can give dividend in these conditions.

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