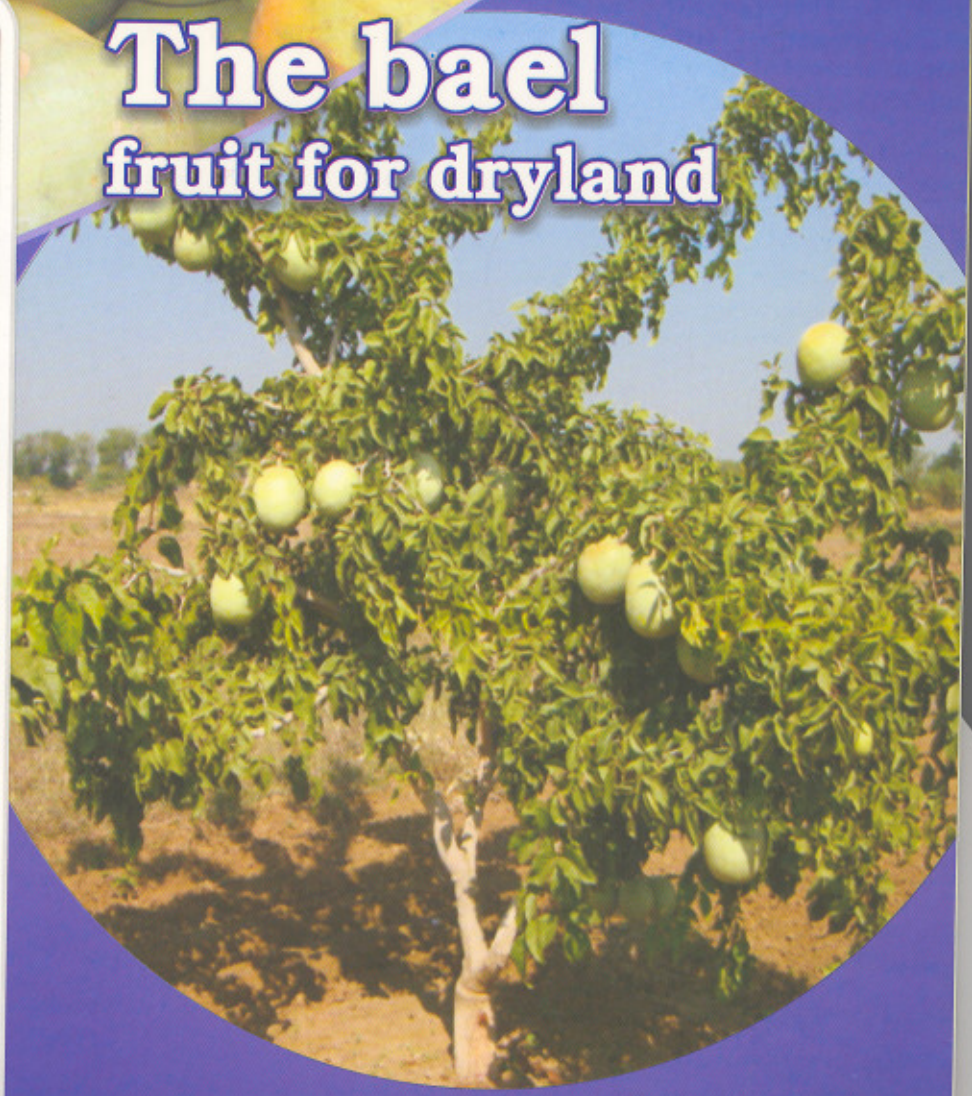
Technical Bulletin No. 38

The bael
fruit for dryland



A. K. Singh, Sanjay Singh, R. S. Singh, B. G. Bagle and B. D. Sharma

Central Horticultural Experiment Station
Vejalpur, Panchmahals (Godhra), Gujarat.

Regional Station of

Central Institute for Arid Horticulture, Bikaner
(Indian Council of Agricultural Research)

The bael
fruit for dryland

A. K. Singh
Sanjay Singh
R. S. Singh
B. G. Bagle
B. D. Sharma

भाकृअनुप
ICAR

Central Horticultural Experiment Station
Vejalpur, Panchmahals (Godhra), Gujarat.

Regional Station of

Central Institute for Arid Horticulture, Bikaner
(Indian Council of Agricultural Research)

Central Institute for Arid Horticulture
(Indian Council of Agricultural Research)
Beechwal, Bikaner-334006 (Rajasthan)

Foreword

Dr. B. D. Sharma
Director

India is the second largest producer of fruit (63.50 million tonnes) obtained from 5.78 million ha area accounting for 10.00% of the world production of fruits. This has been made possible due to concerted efforts of scientists and progressive farming community. In recent years, there is considerable awareness about the nutritional security and food safety. The bael, medicinally important underutilized fruit, is adequately rich in antioxidants and phytochemicals besides some essential nutritional components like vitamins, minerals and dietary fibres. The unripe or half ripe fruit is regarded as astringent, digestive and stomachic. The fruit is used in chronic diarrhoea and dysentery, and is said to act as tonic for heart and brain, and it is useful adjuvant as it helps to remove constipation which hinders the healing ulcerated surfaces of intestine. Fully ripe fruits are eaten fresh, while mature and ripe fruits can also be processed into various value added products like Murabba, jam, squash, powder, slab, toffee, RTS etc.

An area which needs immediate attention in this crop is crop variability through collection, characterization documentation, conservation, development of suitable technologies, utilization and popularization. The demand of this crop is gradually increasing owing to tremendous potential for commercial exploitation aimed at improving the economic status of the poor and marginal farmers. So far, it has received least attention due to lack of awareness about food and nutritional security.

This bulletin deals with package and practices of bael cultivation under rainfed conditions and also to highlight the importance of crop for therapeutical and nutraceutical aspacts and processing. The degraded lands and the area of abiotic and biotic stress can profitably be utilized for commercial cultivation of bael.

It is hoped that it will be useful to the teachers, students, extensionists, policy makers, fruit growers and traders. We hope that this may encourage further production, processing and marketing of bael at village level as cottage industry, and researchers and scientists to further explore the benefits of this indigenous underutilized fruit.

Date : August, 2010
Place: CIAH, Bikaner

(B. D. Sharma)
Director

INDEX

The bael - fruit for dryland

First Edition-2011

Published by
Dr. B. D. Sharma
Director
Central Institute for Arid Horticulture
Shri Ganganagar Highway,
Beechwal Industrial Area, P.O.,
Bikaner-334006 (Rajasthan)
Phone : 0151-2250960, 2250147
Fax : 0151-2250145

Compiled and Edited by
A. K. Singh, Sanjay Singh, R. S. Singh, B. G. Bagle and B. D. Sharma

Printed by :
Mahalaxmi Printing Press
Opp. Civil Hospital, Godhra-389 001.
Tel. : 02672-240494

Cover Photographs :
Various views of Goma Yarhi and Pant Aparna Varities of bael

The bael - fruit for dryland

Introduction

Bael *(Aegle marmelos Correa)* is an important indigenous fruit of India. It is grown in various parts of South East Asia including India, Sri Lanka, Pakistan, Myanmar, Bangladesh, Thailand and most of the South-East Asian countries. In India, bael is being grown throughout the country where it is also known by other vernacular names like bael, bili, bilva, belo, sriphal and bengal quince (John and Stevenson, 1979). The bael tree has found mention in mythological treatises. It is grown near temple of the Lord Shiva in India. According to Hindu customs, the leaves of the tree are considered sacred and offered to the Lord Shiva. In history, the mention of bael tree has been traced to Vedic times (C 2000 B.C.–C 800 B.C.) in the Yajur Veda. Om Prakash (1961) recorded mentions of bael in early Buddhist and Jain literature (C 800 B.C. – C 325 B.C.) describing various methods of ripening of the bael fruit along with some other fruits. In the 'Ramayana' period, the bael fruit was known and its trees were reported to be growing in 'Chitrakuta' hills and 'Panchvati'. In the 'Upavana Vinod, a Sanskrit treatise on silviculture (Majumdar, 1935) and in the 'Brihat Samhita' mention had been made of bael fruit (Aiyer, 1956), as the legend goes, in the forest, Lord Rama performed religious rites by offering various fruits including bael (Aiyer, 1956). Bael fruit has been portrayed in painting of Ajanta Caves along with other fruits (Om Prakash, 1961). Like many other species of Rutaceae family, bael also has fragrant flowers. It is believed that this tree act as indicator plant for tracing of underground water (Singh and Roy, 1984).

Importance

The fruits are mentioned in the Indian Pharmacopoeia. They are also highly valued in *Ayurvedic* medicines. The peripheral part just within the rind is fleshy and thick, and has a pleasant resinous odour. The walls separating the chambers have a light yellow tint, which becomes yellowish brown on exposure and have slightly acrid bitter taste. The chambers are full of amber or honey coloured viscous very sticky or glutinous, translucent pulp, which is slightly sweet and feebly aromatic. The gummy substance surrounding the seeds serves as a good adhesive, and is added to water-paints to improve strength and brilliancy. It is more abundant in young fruits. The gum has been used for the stabilization of drilling fluids. The stem also contains a gum similar to gum arabic.

The importance of bael fruit lies in its curative properties, which make the tree one of the most useful medicinal plants of India (Kirtikar and Basu, 1935).

Its medicinal properties have been dealt with in the 'Charaka Samhita', an early medical treatise in Sanskrit (Aiyer, 1956). All the parts of the tree, whether it is stem, bark, root, leaf, flower, seed oil or fruits of any stage of maturity and ripenings are used in various *Ayurvedic* medicines.

The demand of bael as table fruit is not much higher as other major fruits like mango, banana, guava, apple etc. The ripe fruit is eaten as a fresh and has a more demand amongst those, who wants it for therapeutic use. Sometimes the pulps are diluted with water and add the requisite amount of sugar and tamarind to prepare a delicious cooling drink. The bael pulp is used as a base of various fruit products like squash, jam, slab, toffee, powder, nectar, RTS etc. Green bael fruits are used for preparing murabba (preserve), which is generally taken for stomach ailments. The green bael fruit slices are often dried and stored for future use. The unripe or half ripe fruit is regarded as astringent, digestive stomachic and good for heart and brain (Kirtikar and Basu, 1935). The fruit is used in chronic diarrhea and dysentery and to act as tonic for heart and brain. It is useful adjuvant, as it helps to remove constipation which hinders the healing ulcerated surfaces of intestine. Besides the fruits, the root is an ingredient of 'dasmula' (ten roots) used as *Ayurvedic* medicine. The roots as well as bark are used in the form of a decoction as a remedy in melancholia, intermittent fever and palpitation of heart. Root has anti-amoebic and hypoglycemic properties. The young leaves and shoots are used as fodder for cattle, sheep and goats. The leaves are bitter and used as febrifuge, Poultice made of leaves is used for ophthalimia and ulcers. Fresh leaves are also used as remedy for 'dropsy, and beriberi associated with weakness of heart. The astringent rind of ripe fruits and bark are employed in dyeing and tanning. The timber is commonly used for making pestles of oil and sugar mills, for posts, shafts, axles and naves of cart. The shells of smaller fruits are used as snuff boxes. A yellow dye is extracted from the rind of unripe fruit. The diluted leaf juice is used for catarrh. The alkaloid aegelin present in the leaves are efficacious in asthma. Utilization of bael fruit has been reported by Roy and Singh (1979 a).

Chemical composition

Various chemical constituents viz, alkaloids, coumarins, steroid etc. have been isolated and identified from the different parts of the plants. Bael fruit is one of the most nutritious fruits. Analysis of the bael fruit gave the following values: 61.5g moisture, 1.8 g protein, 0.39 g fat, 31.8 g carbohydrates, 1.7 g minerals, 55 mg carotene, 0.13 mg thiamine, 1.19 mg riboflavin, 1.1mg niacin and 8.0 mg vitamin C per 100 g of edible portion (Gopalan *et al.*, 1961).

Its medicinal properties have been dealt with in the 'Charaka Samhita', an early medical treatise in Sanskrit (Aiyer, 1956). All the parts of the tree, whether it is stem, bark, root, leaf, flower, seed oil or fruits of any stage of maturity and ripenings are used in various *Ayurvedic* medicines.

The demand of bael as table fruit is not much higher as other major fruits like mango, banana, guava, apple etc. The ripe fruit is eaten as a fresh and has a more demand amongst those, who wants it for therapeutic use. Sometimes the pulps are diluted with water and add the requisite amount of sugar and tamarind to prepare a delicious cooling drink. The bael pulp is used as a base of various fruit products like squash, jam, slab, toffee, powder, nectar, RTS etc. Green bael fruits are used for preparing murabba (preserve), which is generally taken for stomach ailments. The green bael fruit slices are often dried and stored for future use. The unripe or half ripe fruit is regarded as astringent, digestive stomachic and good for heart and brain (Kirtikar and Basu, 1935). The fruit is used in chronic diarrhea and dysentery and to act as tonic for heart and brain. It is useful adjuvant, as it helps to remove constipation which hinders the healing ulcerated surfaces of intestine. Besides the fruits, the root is an ingredient of 'dasmula' (ten roots) used as *Ayurvedic* medicine. The roots as well as bark are used in the form of a decoction as a remedy in melancholia, intermittent fever and palpitation of heart. Root has anti-amoebic and hypoglycemic properties. The young leaves and shoots are used as fodder for cattle, sheep and goats. The leaves are bitter and used as febrifuge, Poultice made of leaves is used for ophthalimia and ulcers. Fresh leaves are also used as remedy for 'dropsy, and beriberi associated with weakness of heart. The astringent rind of ripe fruits and bark are employed in dyeing and tanning. The timber is commonly used for making pestles of oil and sugar mills, for posts, shafts, axles and naves of cart. The shells of smaller fruits are used as snuff boxes. A yellow dye is extracted from the rind of unripe fruit. The diluted leaf juice is used for catarrh. The alkaloid aegelin present in the leaves are efficacious in asthma. Utilization of bael fruit has been reported by Roy and Singh (1979 a).

Chemical composition

Various chemical constituents viz, alkaloids, coumarins, steroid etc. have been isolated and identified from the different parts of the plants. Bael fruit is one of the most nutritious fruits. Analysis of the bael fruit gave the following values: 61.5g moisture, 1.8 g protein, 0.39 g fat, 31.8 g carbohydrates, 1.7 g minerals, 55 mg carotene, 0.13 mg thiamine, 1.19 mg riboflavin, 1.1mg niacin and 8.0 mg vitamin C per 100 g of edible portion (Gopalan *et al.*, 1961).

No other fruit has such a high content of riboflavin. Tannic acid is only phenolic substances detected from bael fruits. The fruit contains allo-imperatorin, marmelosin identical with imperatorin and β-sitosterol. Chakraborty *et al.* (1978) reported that marmolide, an isomer of imperatorin, which exhibits tyrosinase- accelerating and tryptophan pyrolase-inhibiting furocoumarin were isolated from ripe fruits. The fruit yields two per cent water soluble dried gum. Hydrolysis of the gum gave: galactose, 20.4%, arabinose, 10.7%, D-galacturonic acid, 25.2% and traces ofrhamnose (Haskar and Kendulkar, 1961). Compounds like auroptin, marmin, umbelliferone and lupeol have also been found in the bark of bael (Patra *et al.* 1979). Occurance of auroptins, umbelliferone, marmin, lupeol and skimmianine has also been reported in roots (Chatterjee and Choudhary, 1960). Besides of these compounds, psoralen, xanthotoxin, scopoletin and tembamide have also been isolated from the roots of bael (Shoeb *et al.,* 1973).The presence of Aegeline an alkaloid has been reported in the leaves of bael fruit (Chatterjee and Roy, 1957). Analysis of the leaves gave the following values (dry basis): crude protein, 15.13, ether extra, 1.54, crude fibre, 16.45, N-free extra, 52.83, ash, 14.05, calcium, 5.93 and phosphorus, 0.69 per cent. Marmelosin is probably most therapeutically active compound present in bael fruit (0.03-0.37%) and vary according to variety and locality (Dixit and Dutt, 1932). The mature bark contains marmin, auropotins, umbelliferone, lupeol and skimmianine (Chatterjee and Bhattacharya, 1959).The bael fruit mucilage on hydrolysis shows the presence of three reducing sugars, galactose, arabinose and rhamnose (Parikh *et al.,* 1958). The wood contains a furoquinoline alkaloid, dictamnine, marmesin and neutral compound. The seed yields oil 34.4% on dry basis and the fatty acid composition of oil as follows: palmitic, 16.6; stearic, 8.8; oleic 30.5; linoleic, 30.0; and linolenic, 8.1 per cent. Bael seed contains 62% protein and 3% each carbohydrate and ash (Banerjee and Maiti, 1980).

Area and distribution

So far there is no organized orcharding of bael in our country, hence exact data on acreage and production are not available. However, in recent years, concerted efforts have been made for collection of elite genotypes of bael from all over the country and their evaluation and establishment of germplasm block at ICAR Institutes/ Regional stations and State Agricultural Universities. The bael is grown in India and in neighboring countries namely Nepal, Sri Lanka, Pakistan, Bangladesh, Myanmar, Thailand and most of the South East Asian countries. In India, it is distributed throughout the country, but concentrated

area under bael is in eastern parts of the Gangetic plains and nearby areas particularly in Uttar Pradesh, Bihar, West Bengal and Orissa. Its trees are also available in wild state in sub-Himalayan tract from Rajasthan to west Bengal, central and southern India. In Gujarat, bael trees are found growing naturally in the forest with great diversity (Singh *et al.,* 2008 b). Most of the genotypes available in Gujarat are having small size fruits (Singh *et al.,* 2008a). Apart from systematic orchards, bael trees are also planted in nutritional gardens, parks, temple gardens, roadsides for various purposes. It was introduced into Europe from India in 1759 (John and Stevenson, 1979).

Soil and climate

Bael tree is very hardy, deciduous and can thrive well in swampy, alkaline and stony soils having pH range from 5.0 to 10.0 (Jauhari and Singh, 1971). Its trees are cold hardy and found to be grown up to an altitude of 1200 m above mean sea level. It has wide range of adaptability to adverse soil and climate. Under hot semi-arid ecosystem, the extent of hardiness of bael plants has also been observed and the plants are giving good yield in rainfed conditions. The extent of hardiness of bael plants under thar desert have also been observed that the plant even after being buried under sand for 2-3 months are capable of rejuvenating itself (Anon 2001). Marked reductions in the contents of leaf NPK and Ca were observed in response to increase in salinity and sodicity level in the soil in which plants were grown. Salinity caused significant increase in leaf Mg, while sodicity decreased it. Leaf Na was at toxic levels in both saline and sodic soils (Shukla and Singh, 1996b).

Bael is bestowed with a natural characters for being tolerant to the extremes of temperature and soil moisture stress by shedding its leaves during summer and

However, young plants need to be protected from low temperature (4^{0}C) and desiccating hot winds. It can also be successfully grown in saline, sodic and sandy wasteland provided the soil is treated with gypsum and pyrite before plantation.

Botany and Morphology

Aegle marmelos Correa belongs to the family Rutaceae. Other members of Rutaceae are *Citrus, Casimiroa, Clausena, Eremocitrus, Limonia, Feroniella, Fortunella, Poncirus, Triphasia* etc. The genetic name *Aegle* is of Greek origin and the species *marmelos* is of Portuguese origin. The chromosome number is x=9 and 2n=36. The tree is a medium to tall, deciduous, slow growing up to the height of 5-10 m. Its leaves are green aromatic trifoliate; often branches have spines and trunk is strong and stout.

The leaves are divided into three leaflets, *i.e.* a pair and a terminal one; the terminal one is usually the largest. Some leaf abnormalities of *Aegle marmelos* have been noticed. Generally the branches are unusual with long, straight spines. The bark is shallowly furrowed and corky. The bisexual flowers are nearly 2 cm wide and borne in clusters, sweet scented and greenish white. The calyx is shallow with 5 short, broad teeth, pubescent outside. There are 5 petals which are oblong oval, blunt, thick, pale greenish white, dotted with glands. Stamens are numerous, sometimes coherent in bundles. The ovary is oblong ovoid, slightly tapering, the axis being wide; cells are numerous 8-20, small and arranged in a circle, with numerous ovules in each cell. The ripe fruits are woody, large, spherical, up to 23 cm in diameter, oblong or pear shaped, with a more or less smooth or slightly tuberculate surface. The fruit is usually globose with a pericarp nearly smooth, grayish yellow, 1.6-2.7 mm thick, hard and filled with soft, yellow and orange, very fragrant and pleasantly flavoured pulp. Botanically, the fruit is berry amphi saraca with hard pericarp. The number of cells in the fruit, arranged in a circle, is equal to the number of cells in ovary. Seeds are numerous, compressed and arranged in closely packed tiers in the cell surrounded by very tenacious, slimy, transparent mucilage, which becomes hard when dry. The testa is white with wooly hairs and the embryo has large coty ledons and a short superior redicle. Pollination entemophilly, usually by honeybee. The nectar secreting disc found beneath the ovary is main source of attraction for the insects (Reuther *et al.*, 1967, Srivastava and Singh, 2000, Singh, 1989, Pal and Mishra, 2005, Singh and Mishra, 2004 and Singh *et al.*, 2007).

Buds in bunch

Flower buds

Flowering

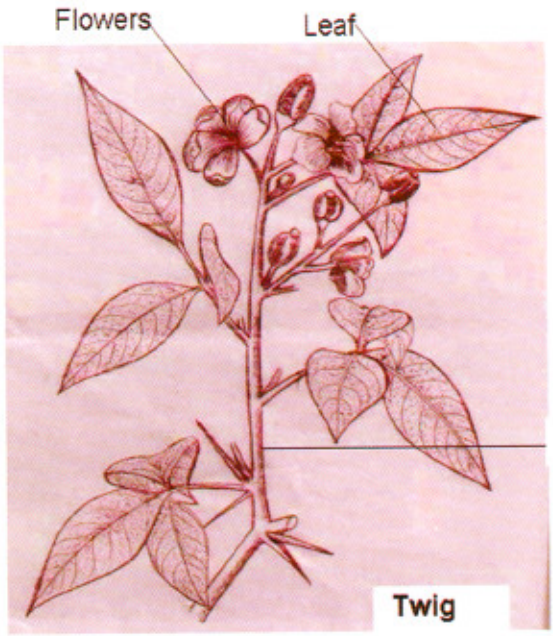
Flower bud emergence, flowering duration, time of anthesis, dehiscence of anther, stigma receptivity and pollen viability vary according to variety and locality (Srivastava and Singh, 2000). Size and shape of floral organs in terms of bud size, flower size, petal size, etc. of the varieties evaluated at CHES, Godhra under rain fed condition of semi-arid ecosystem according to Singh *et al.*, (2008c) is given in Table 1&2.

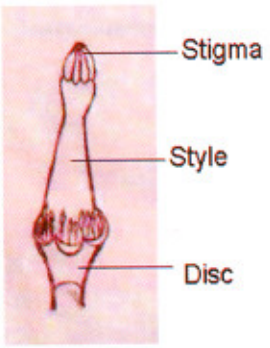
Table 1: Flowering behavior of bael varieties

Varieties	Flower bud emergence			Flowering period		
	Start	Peak period	End	Start	Peak period	End
CISHB-1	20 April	24-29 May	16 June	22 May	8-12June	18 June
CISHB-2	30 April	23-28 May	20 June	24 May	7-14 June	22 June
NB-5	3 May	24-29 May	22 June	26 May	10-15 June	24 June
NB-7	2 May	25-30 May	15 June	22 May	7-12 June	17 June
NB-9	5 May	25-30 May	23 June	15 May	10-18 June	24 June
NB-16	7 May	24-29 May	26 June	14 May	10-20 June	25 June
NB-17	30 April	23-28 May	20 June	24 May	7-14 June	22 June
Pant Aparna	5 May	24-29 May	16 June	15 May	9-14 June	18 June
Pant Sujata	1 May	25-30 May	15 June	22 May	7-12 June	16 June
Pant Shivani	2 May	25-29 May	20 June	23 May	10-15 June	17 June
Pant Urvashi	8 May	25-30 May	23 June	15 May	10-18 June	24 June
Goma Yashi	21 April	16-23 May	19 June	12 May	9-16 June	14 June

Table 2 : Morphomatrics of floral organs of different bael varieties

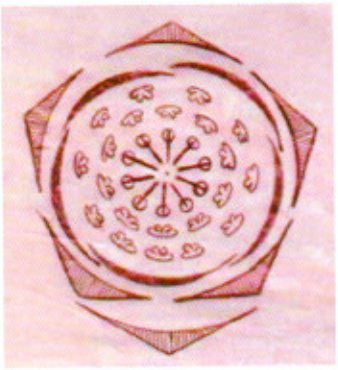
Varieties	Flower size (mm)		Bud size (mm)		Petal size (mm)		Pedicel size (mm)	
	Length	Width	Length	Width	Length	Width	Length	Width
CISHB-1	14.00	35.00	11.00	7.00	15.00	7.00	07.50	2.00
CISHB-2	19.00	26.00	13.00	9.50	13.00	8.00	06.50	2.00
NB-5	14.15	29.00	11.50	8.00	18.00	7.50	10.50	2.50
NB-7	18.00	35.00	13.00	9.50	19.00	9.00	05.50	2.50
NB-9	12.00	25.00	11.00	8.00	11.00	7.00	04.00	2.00
NB-16	14.00	28.00	11.00	8.00	12.00	7.00	04.50	2.00
NB-17	18.00	34.00	13.00	9.50	18.00	9.00	05.00	2.50
Pant Aparna	16.00	30.00	10.00	9.00	18.00	10.00	10.00	2.50
Pant Sujata	15.15	29.00	12.50	8.00	17.00	7.50	09.50	2.50
Pant Shivani	15.00	30.00	11.00	7.50	18.50	8.00	09.50	2.00
Pant Urvashi	15.00	26.00	11.00	8.50	16.00	9.00	7.00	2.50
Goma Yashi	12.00	22.00	12.00	8.00	15.00	9.50	6.50	2.00



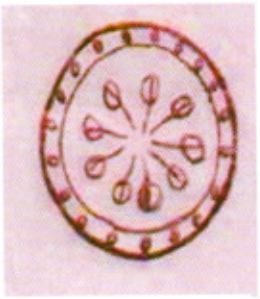


Gynoecium

T. S. of fruit



Floral diagram



T. S. of overy

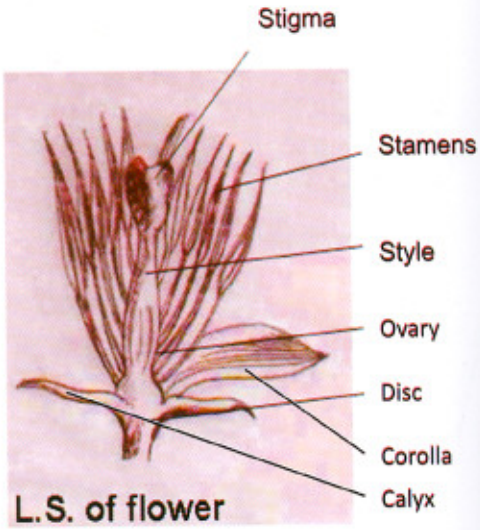


Fig.1.Taxonomic description and diagramatic representation of bael flower

Improvement

For the popularization of bael, improvement in terms of higher productivity per unit area and quality of fruits in terms of percentage of edible portion, colour, shape, taste and flavour are important. Generally, bael is raised through seeds leading to great variability in morphological characters, bearing behaviour, size and shape of fruit, physical composition of fruit viz, pulp, mucilage, fibre, peel and chemical composition in terms of TSS, total sugar, phenolics and vitamin C, etc. There is a wide genetic diversity in the existing population. This provides ample scope for selection of genotypes for improvement.

In view of the limitations of the conventional breeding techniques, biotechnological approaches for bael improvement hold great potential. Strategies emanating out of advances made in plant biotechnology include embryo rescue, somaclonal variation, haploidy, protoplast fusion, *in-vitro* conservation of germplasm and recombinant DNA technology (genetic engineering). Genetic maps of species may be prepared with the use of molecular markers.

Varietal wealth

Previously, bael fruits are generally named after the locality where they are easily available. So far, reports on the available cultivars are mainly from the states of Uttar Pradesh, Uttarakhand, Bihar and West Bengal. Singh (1961) described six varieties of bael from U. P. viz Mirzapuri, Darogaji, Ojha, Rampuri, Azamati and Khamaria. Teaotia *et al.* (1963) reported five varieties from Uttar Pradesh and 'Kaghji Gonda' was reported to be the best. It appears that the organoleptic quality of bael fruit depends upon three factors: mucilage, sugar and total phenolics. High sugars, particularly non-reducing sugars with low phenolics and mucilage, make the bael fruit more palatable. It has been observed that the bigger size fruits have high pulp, often thick peel, less seeds, less sugar, low phenolics and less mucilage as compared to smaller ones. Bael trees with desirable fruit characteristics have been collected and evaluated for their growth, flowering, fruiting behaviour and quality attributes and many promising varieties have been developed through clonal propagation at ICAR Institutes / Regional Station and State Agricultural Universities.

Table 3: Improved bael varieties developed in India

Varieties	Organizations from where developed
Narendra Bael-5, Narendra Bael-7 Narendra Bael-9, Narendra Bael-16 Narendra Bael-17	N. D. University of Agriculture and Technology, Kumarganj, Faizabad, U. P.
Pant Aparna, Pant Sujata Pant Shivani, Pant Urvashi	G.B. Pant University of Agriculture and Technology, Pant Nagar, Uttarakhand
CISHB-1 CISHB-2	Central Institute for Sub-tropical Horticulture, Lucknow, Uttar Pradesh
Goma Yashi	Central Horticultural Experiment Station (CIAH), Vejalpur, Panchmahals (Godhra), Gujarat

Description of varieties

The detailed description of varieties of bael is given below:

Narendra Bael-5

The plants are small and semi-spreading growth habit, precocious and prolific in bearing. The budded plants start fruiting in the 4th year. The average fruit yield of six-year old plant is 28.78 kg. The fruits are medium in size (12.50 cm x 11.50 cm), round, with smooth surface and very thin rind (0.16-0.17cm), straw yellow at maturity, low in mucilage, moderately fibrous and an attractive light yellow pulp, with low seed content. Excellent in taste and flavour, the fruits have 33^{0}Brix total soluble solids in pulp and 48 ^{0} Brix in mucilage and ascorbic acid 18.63 mg/100g of edible portion. The fruit weight ranged from 0.8-1.0 kg under rain fed conditions of semi-arid ecosystem during sixth years of orchard life. Its taste is good and can be used as fresh and also after proceshing into various value added products.

Ripened fruit NB-5

NB-5

Narendra Bael-9

The plants are semi-vigorous and spreading having compact canopy. The variety is precocious and prolific bearer. The average fruit yield of a six-year old plant is 56 kg. Fruits are medium to large in size (16.00 cm x 13.50cm), roundish-oblong, with smooth surface and thick rind (0.31cm), light yellow at maturity, average in mucilage, moderately fibrous, slightly golden-yellow pulp with low seed content. The fruits are good to taste containing total soluble solids 38^0 Brix in pulp and 41^0 Brix in mucilage, slightly acidic and ascorbic acid 19.20 mg/100 g of edible portion. It can be used as fresh as well as processed into various value added products. Its keeping quality for storage is very good.

Mature fruit

Tree in bearing

Narendra Bael-7

Plants are tall and semi-spreading. They are sparse in bearing with large size fruit. The budded plants start fruiting in the 4th year. The average fruit yield of six-year old plant is 32.10 kg (6th year). The fruits are medium to large in size (18.25cm x 22.50 cm), round and with smooth surface and very thick rind, yellow at maturity, low in mucilage and fibres with an attractive yellow pulp, and low seed content. Fruits are good in taste and flavour, having total soluble solids 30^0 Brix in pulp and 42^0 Brix in mucilage, slight acidity and 19.78 mg/100 g ascorbic acid. It is highly suitable for processing.

Developing fruit

Harvested fruit,

Pant Aparna

Its trees are dwarf with drooping foliage, almost thornless, precocious and heavy-bearer. The leaves are large, dark green and pear shaped. Fruit has globose

Ripening Fruits

shape with average size of fruit 13.00 cm x 12.00 cm and weight of 0.8-1.25 kg. Fruit pulp is yellow and rind is thin. TSS 34 ^{0} Brix in pulp and 47 ^{0} Brix in mucilage, titratable acidity 0.67% and ascorbic acid 17.15 mg/100 g of pulp. Mucilage, seed and fibre are low. Mucilage and seeds are enclosed in separate segments. Flavour and taste are very good. Yield during 6th year is 40.25 kg/plant.

Bearing Tree

Pant Shivani

It is an early mid-season variety. Trees are tall, vigorous, dense, upright growing, precocious and heavy-bearer. Fruit shape is ovoid, oblong and the size being 18.50 cm x 15.00 cm. Fruit weight ranges from 2 to 2.4 kg. Colour of fruit is lemon-yellow and its storage quality is good. Rind is medium-thin, pulp is lemon-yellow with pleasant flavour and mucilage, seeds and fibre are low to medium. Taste is very good. It has 69% pulp, TSS 36 ^{0} Brix in pulp, mucilage TSS 48 ^{0} Brix, total titratable acidity 0.47% and ascorbic acid 19.55 mg/100 g of flesh.

Fruit ripening at tree

Pant Sujata

It is an early mid-season variety but has problem of fruit splitting, although it has not been reported under rainfed conditions of hot semi-arid ecosystem of western India. Trees are medium-dwarf with drooping and spreading foliage, dense, precocious and heavy bearer. Thorns are stout and bigger. Fruit is globose shaped, depressed at both ends withaverage size of 14.50 cm x 13.50 cm and weight varied from 1.12 to1.40 kg under rainfed condition of hot semi arid ecosystem of western India. Fruit and pulp are light yellow. Storage life is better, rind is thin, and seeds, mucilage and fibre are low. Its flavour is pleasant a nd taste is very good. Pulp is 64%, TSS 32^0 Brix in pulp and 42^0 Brix in mucilge, acidity 0.44% and ascorbic acid 17.10 mg/100 g of flesh.

Harvested fruits

The bael - fruit for dryland

Pant Urvashi

Ripening fruit

Bearing tree

It is a mid-season variety. Trees are tall, vigorous, dense, upright growing, precocious and heavy bearer. Fruit is ovoid-oblong with average size of 14.50 cm x 17.20 cm and fruit weight ranges 1.5-2.50 kg. Fruit is yellow, rind is medium to thin and pulp is light yellow. Fruit has 62.35% pulp with pleasant flavour. Seeds and mucilage are medium, fibre content low, TSS 33^0 Brix in pulp and 41^0 Brix in mucilage, titratable acidity 0.49% and ascorbic acid 17.15 mg/100g pulp.

CISHB-1

It is early maturing variety. The plants are semi-tall and having spreading growth habit. The budded plants start fruiting in the 4^{th} year. The average fruit yield of six-year old plant is 42.64 kg. The fruits are medium in size (16.50 cm x 12.00 cm), oval-oblong, with smooth surface, yellow at maturity, low in mucilage and fibrous, an attractive yellow pulp, with high seed content. Excellent in taste and flavour, the fruits have 32^0 Brix total soluble solids in pulp and 43^0 Brix in mucilage. The fruit weight varies from 0.8 to 1.40 kg under rain fed condition of western India.

Ripening fruit

Growth behaviour

CISHB-2

The plants are dwarf and spreading. The average fruit yield of six-year old plant is 38.45 kg. The fruits are medium in size (16.00 cm x 14.00

Mature fruit CISHB-2

Bearing tree at maturit y

surface, yellow at maturity and the rind is thick, low in mucilage and fibrous, an attractive yellow pulp, with low seed content. Good in taste and flavour, the fruits have total soluble solids 31^0 Brix in pulp and 38^0 Brix in mucilage, titratable acidity (0.41%). The fruit weight ranges from 1.7 to 2.6 kg/fruit.

Goma Yashi

It is early maturing variety, semi-spreading, drooping growth habit, less lateral branches growth (20-35 cm annually), small tree relatively low stature, spineless, central leaf size (13.20x6.70 cm), lateral leaf size (9.20x5.30cm), ovate having acute apex.

Fruits in cluster

Developing fruit

Budded plants of Goma Yashi starts flowering in 3rd year. Initiation of flowering (last week of April), end of flowering (last week of June), bud size (12 mm x 8 mm), flower size (15 mm x29 mm), petals (4-5), anthesis (6 A.M -8 A.M) and dehiscence period (6.30 A.M 0-8.30 A.M).

Yield (51.00 kg 6thyear), fruit size (13.00 cm x 12.50 cm), fruit girth (41-45 cm), shell thickness (0.17cm), seed weight (25- 30g), fibre weight (40.24-51.20g), shell weight (180-210g), fruit weight (1.00-1.62 kg), locules in cross section (13-15), TSS pulp ($35\text{-}39^0$B), TSS mucilage ($41\text{-}43^0$B), titratable acidity (0.26-0.32%) and vitamin C (22.00 mg/100 g pulp).It is highly suitable for high density planting.

Fruit ripening (bunch)

Plant propagation

Traditionally, bael is propagated by seeds, however, inherent limitations associated with the seedling progenies; seed propagation is limited for the raising of root stocks only. True to type planting materials can be produced through vegetative means only. Methods of vegetative propagation have been reported by Singh (1954). The bael fruit can be grafted on number of related species, such as *Aegle fraeqlegabonensis, A.chevlieri, A. paniculata and Swinglea glutinosa* (Hays, 1957).

Seed

Seed propagation is the most common method of propagating bael. Bael seeds have no dormancy; hence fresh seeds can be sown 2 cm deep in the nursery within 10-15 days. The fresh bael seeds germinate in 8-15 days after sowing. The seedlings become ready for transplanting in spring or next Monsoon. If the seeds are sown too deep, seedling emergence is delayed and there may be chance of rotting due to poor aeration. Seeds may also be sown in polythene bags, as it facilitates an easy handling of rootstocks and grafted plants. The orchard raised by seedlings is not true to type and exhibits variability. Therefore, vegetative propagation techniques are recommended for commercial orcharding of bael. Among the vegetative propagation techniques, budding, grafting, layering and root suckers are most successful for methods of multiplication of bael. Now-a-days, patch budding and soft wood grafting have been adopted for multiplication of bael commercially.

Raising of seedlings in nursery beds

For raising of seedlings in the nursery, beds are thoroughly cleaned and ploughed. For better germination, higher survival and establishment, well rotten FYM should be mixed with the soil before sowing of seedlings. Fresh seeds can directly be sown because of no dormancy. Young seedlings should be protected from frost during winter under arid ecosystem. Polyethylene tubes can also be used to raise the seedlings. Mixture of FYM, sand and soil (1:1:1), should be mixed before filling in the polythene tubes. Seeds are sown in the polythene tubes or bags during rainy season for better germination and survival. Delayed and poor seed germination and reduced plant growth were observed in response to increased sodicity (Shukla and Singh, 1996a). Performance of bael with respect to seed germination and plant growth was observed satisfactory in sodic soils up to 29 ESP without application of any chemical amendments. The media requirement for seed germination and seedling establishment has also been suggested by Chattopadhyay and Mahanta (1989).

The foliar sprays of plant growth regulators *i.e.* gibberellic acid (GA_3) and IBA (both at 250, 500, 750 and 1000 ppm), and potassium nitrate (250, 500, 750 and 1000 ppm) improves seedling vigour by means of improved growth of stem and roots.

Raising root stocks in polyethylene bags

Raising of rootstock in nursery beds and lifting of budded plants with earth ball in highly sandy soils is practically not feasible. Transportation of plants for a long

distance may also cause high mortality particularly under hot semi-arid and arid environment. To reduce the time for raising root stock and to avoid damage during handling and transportation, polyethylene tubes and polyethylene bags may be used on commercial scale. Generally, polyethylene bags (25cm x 10cm) are used for raising the rootstocks. Small holes are made in the bottom and sides of polythene bags for drainage and aeration, and the bags are filled with porous rooting medium or pot mixture for raising rootstocks. Generally, 1-2 seeds are sown in each poly bags and then placed in trench bed, so that it can be irrigated easily. Sometimes coiling of root is become problem, hence root pruner is also used for trimming of roots. Polyethylene bags of the size of 25 cm x10 cm, 25cm x 15 cm and 30 cm x 15cm as per the requirement are being used for raising the rootstocks in India. Seeds can also be sown in the raised nursery beds in open or playhouses and transplanting of very young seedlings (2-4 leaf stage) in the polythene bags gives 82.00 % success. Growth of the rootstocks can be improved with the application of 1g/ litre urea solution. About 8-12 months old seedling of uniform size having stem of pencil thickness are used as rootstock for budding and grafting. Plants raised in the polythene bags can easily be transported to distant places with higher planting success.

Rootstocks raised in the field

For getting maximum survival and success of budding under rain fed conditions of hot semi-arid ecosystem, sowing of seeds may be done directly in the field during monsoon (June-July) at demarcated location, and the seedlings become ready for *in-situ* budding during June, 10-11 months after sowing. If there is long gap between two spell of rain, 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 tap roots and thus become more hardy and vigorous after *in-situ* grafting or budding.

Root stock

Rootstock selection for vegetative propagation of bael is important, as it controls the vigour and equilibrium between yield and quality. Dwarfing rootstocks induce dwarfness and facilitate easy management of the orchard. Generally, seeds of deshi plants are used for raising root stocks in nursery, but it can also be grafted on

the *Aegle fraeglegabonensis, Aeglopsis chevalier* and *Aegle paniculatum*. However, these speices are not commonly used for raising of bael plant.

Vegetative propagation (Budding)

Selection of bud wood

Bud wood becomes available during the active growth period in rainy season. The bud sticks (1-2 months old), with well swollen and recently matured buds (but still not open) are collected. Immature and undeveloped buds from the upper part of the new shoots are not suitable. Similarly, over mature and inactive buds should not be used. The active growth period is indicated by easy and clear separation of the bark from the wood of scion sticks. After collection, the bud wood is often stored for some period or takes same time in transportation. During this period, considerable loss of survivability may take place. Bud woods retain good survival when kept under ventilated shade and wrapped in moist jute cloth.

Patch budding

In this method, a healthy bud is selected from the axils of leaf. Leaf blade is removed with the help of a sharp knife leaving petiole intact. The upper cut is given about 1-1.5 cm above bud which goes downwards up to 1.0-1.5 cm below the bud without wood portion and then lower cut is given about 1.0 cm below the bud. The similar rectangle incision is made on the rootstock by placing the bud on the root stocks to mark 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 open space, if any, and tied tightly except the place of bud with white polythene strip (200 gauge thickness and 2 cm wide). In case, the cuts on rootstock are wider, at least one side bark of scion and stock must be matched properly. The rootstock is cut about 10 cm above the bud to facilitate bud to sprout. After union, the top of the rootstock is cut a little above the bud union and polythene strips are removed carefully. Time of budding influence the survival of plant in the different varieties. Singh *et al.* (1976) reported 100 per cent bud take during months of June or July. Effect of scion genotypes on patch budding in bael has been reported by Mishra and Jaiswal (2009).

One year old, 0.8-1.20 cm thick rootstocks budded in June-July showed better success. *In-situ* patch budding was found successful when performed in the month of June under Gujarat conditions. In India, patch, forkert and shield methods of budding are generally employed.

In-situ patch budding

In bael, the tap root system is very vigorous. The root system is, therefore, disturbed during the process of planting of grafts, which ultimately affects growth and establishment adversely in the field conditions. Therefore, *in-situ* patch budding has been tried at Central Horticultural Experiment Station, Panchmahals (Godhra), Gujarat. The plants propagated by *in- situ* patch budding in the month of June- July recorded the maximum success (94.14% and 90.82% respectively). For getting better success and survival of plant, patch budding may be practised in the month of June for multiplication of bael genotypes for establishment of orchards. Budding in bael in June- July from one month old scion gave 80 per cent success and patch budding is an ideal method of bael multiplication (Singh, 1954, Moti and Chaturvedi, 1976, Singh *et al.,* 1976, Kumar *et al.* 1994, Chadha, 2001).

In-situ patch budding

In semi-arid regions, *in-situ* budding is the most successful method for establishing of bael orchard. This is done by sowing 2-3 seeds directly in the field or by planting seedlings. After one year, budding is done in the field. This method not only saves time but also ensures higher success. Generally 2-3 rootstocks sprout developing from ground level are budded and ultimately only one of them is allowed to grow which encourages the growth of scion shoots. Sprouts emerging from the rootstock portion should be removed from time to time. Top working of old and uneconomic trees can also be done by heading them back during March and budding on the new shoots during June-August.

Table 4: Standards for Patch budding in bael under semi-arid ecosystem.

Type of rootstock	Straight & active growth stage
Raising rootstock	In polyethylene bag
Size of polyethylene bag	25 cm X 15 cm
Age of rootstock	8 to 12 month old
Diameter of rootstock	0.80 – 1.20 cm
Age of scion shoots	1- 2 month old
Diameter of scion	0.70 – 1.20 cm

Size of patch	1.5-2 cm X 1cm
Budding height	20-25 cm above the ground
Bud union	Smooth
Plant height	45-60 cm
Root type/ Architecture	Well developed root system without coiling
Foliage	Healthy and green foliage having 3 to 4 branches
Disease/Pest incidence	Plant should be from insect, pests and diseases.
Precautions	Shifting of polybags in nursery is required at one and half months intervals to discourage tap root. Grafts are to be handled carefully during lifting, packaging and transportation to avoid damage to the union or scion portion.

Use of poly containers for budding

In bael, the size of polythene standardized for optimum seedling vigour, root growth and budding success at CHES, Godhra, revealed that out of four types of polythene bags (25 cm x 15 cm, 25 cm x 10 cm, 30 cm x 8 cm and 20 cm x 8 cm), the maximum number of buddable rootstocks (94.00 %) and buddding success (80 %) was recorded in 25cm x15 cm size bag followed by 25 cm x 10cm (90.50% and72 % respectively) after 11 months of seed sowing. Looking into the transportation problem, 25 cm x10 cm size is, therefore, recommended for use under semi- arid ecosystem of western India.Raising of rootstocks in poly container not only make the transportation of plants easy, but also avoid mortality during transition. Polythene tubes and polythene bags may be used on commercial scale for multiplication of plants. Polythene bags (25cm x 15cm) are used for raising the rootstocks. Small holes are made at the bottom and sides of polythene bags for drainage and aeration and filled with porous rooting medium or pot mixture for raising rootstocks. Generally, one to two seeds are sown in each polythene bags and then placed in trench beds so that it can be irrigated easily. Sometimes coiling of roots becomes problem due to delayed shifting, hence root may also be pruned to avoid its coiling.

Soft wood grafting

About 15-20 cm long mature shoots (2-4 months old) are defoliated 10-12 days prior to grafting operation. These shoots are detached from the mother plant with the help of secateur or sharp grafting knife for grafting by cleft method. For this, seedling rootstock is cut at 20-25 cm height and the top portion is removed.

With the help of knife, 5 cm long vertical downward incision is made in the center of the rootstock. A sharp cut of 5 cm is made on both the sides on the base of the scion shoot to make wedge shape. Thereafter, prepared scion is carefully inserted in vertical slit of the rootstock and tightly secured with the help of 200 gauge thick and 2cm wide polythene strips. The polythene strips should carefully be removed after completion of the union. Maiti *et al.* (1999) reported that bael can be propagated successfully and among different grafting methods tried; whip grafting had given good response (70% success). Recently softwood grafting during June-July has also been found successful with more than 85 per cent success in bael under semi-arid ecosystem of western India.

Soft wood grafted plant

In-situ soft wood grafting

Pits of 1m x 1m x 1m size should be prepared at desired distance (generally at 8m x 8m or 10m x 10m) during March-April and left open during summer for solarization, which kills most of the soil dwelling insect pests and disease causing agents. The pits are filled with a mixture of top soil and 20-30 kg well- rotten farmyard manure. In order to ward off the seedlings from the attack of termites, pit may be drenched with Chlorpyriphos (2-3 ml / litre water). The pit filling is raised up to 15-20 cm above the ground level for proper settlement after rainfall or irrigation.

With the onset of the monsoon season in the middle of the June, seedlings grown in polythene bags are planted in the field during the first week of July. The polythene bags are carefully removed and seedlings are planted in the centre of the pit. The tap root system should not be disturbed while lifting the plants from nursery. After planting, the soil around the plants is pressed firmly to avoid formation of air pockets. Thereafter, basin is prepared around the plant for irrigation or collection of rain water. After planting, seedlings are irrigated thoroughly and thereafter, as per need. The seedlings are ready after one year for planting in the field after the commencement of the monsoon. Seeds may also be sown directly in the field if irrigation water is available for summer irrigation, otherwise the seeds should be sown directly in the field during rainy season under rainfed condition.

In- situ soft wood grafting through cleft method is done in the month of June-July under semi-arid environment of western India. The growth below the graft union is removed regularly to encourage the sprouting and subsequent growth of the scion shoots. The bud sprouts within 15 to 20 days of grafting with proper

establishment of bud's vascular connection with rootstock. The polythene strips are carefully removed after completion of the union. The plants are given support with the help of stakes to protect them from stormy winds. High temperature and relative humidity during June - July has helped in early sprouting and better graft success, because of fast establishment of vascular connection with rootstock.

Table 5 : Standards for soft wood grafting in bael under hot semi-arid ecosystem.

Method of propagation	Soft wood/Wedge grafting
Type of rootstock	Straight & active growth stage
Raising rootstock	In polyethylene bag
Size of polyethylene bag	25 cmX 15 cm
Age of rootstock	9 to 11 months
Diameter of rootstock	0.8 – 1.2 cm
Age of scion shoots	2 -3 months old
Diameter of scion	0.8 – 1.2 cm
Length of scion sticks	12 - 15 cm
No. of buds on the scion stick	5-8 buds
Grafting height	20-25 cm above the soil
Root type/ architecture	Well developed root system without coiling
Plant height	45-60 cm
Foliage	Healthy and green foliage with vigorous growth
Disease/pest incidence	Plants should be free from insect, pests and diseases
Precautions	Shifting of polybags in nursery is required at one and half months intervals to discourage tap root. Grafts are to be handled carefully during lifting, packaging and transportation to avoid damage to the union or scion portion.

Planting of graftedplants

Budlings prepared in the nursery beds are lifted with large earth balls 9 to 12 months after budding for transplanting in the field. Plants may be lost due to damage occurred during lifting, packaging, transporting and planting. These operations are also cumbersome and incur high costs due to the large size of the earth balls. Budlings prepared in polythene bags become ready for transplanting after 50-60 days of budding or grafting. The budlings in bags are removed from the

nursery and kept in the shade for a week and these can easily be transported and planted in the field with maximum survival. The roots of the plants do not coil and therefore, retain the drought hardy character and vigour almost similar to the plants raised *in-situ*.

Inarching

Bael can be propagated by inarching but it is not adopted commercially. In the months of June-July, one-year-old rootstocks are inarched with the matching scion thickness. At the time of inarching, the seedling rootstock should be the thickness of pencil. The rootstocks are placed near a one season old scion shoots of equal thickness, on the mother tree. At 25 cm above ground level, 5 to 8 cm long slice of bark and small portion of wood is removed from the rootstock, thus such incision removes about one third of the thickness of the stem and tapers gently towards the top and bottom. A corresponding cut is made on the scion shoot, so that these two cuts fit perfectly without leaving a chink. The two cuts are placed face to face and tied firmly with gunny string (*sutli*). July is the appropriate time for inarching in bael. There should be no rain at the time of operation. Otherwise, water gets inside the union and causes rotting of tissues. The plants are regularly watered, if there is no rain till the union takes place. The scion shoot is given a cut up to half of its thickness below the union. After 10 days, if the scion shows no wilting, the cut is completed. After another two weeks, the top of the root stock is cut off above the union.

Cutting

Bael can be propagated through stem and root cuttings. It is not a commercial method of propagating bael. Maximum success can be obtained by using growth regulators.

Root cuttings

Bael can be propagated successfully by root cutting aslo. Separation and planting of root suckers can be done during monsoon. To ensure establishment, suckers are planted in nursery beds for about two years after uprooting and are then shifted to the main field. Some root suckers, which arise from the roots of the bael trees having profuse roots, can be separated during Monsoon and directly planted into field. But the success percentage is very low. It is not recommended for arid and semi-arid conditions.

Stem cutting

Bael can also be propagated through cutting and air layering on its own roots. Ray and Chatterjee (1996) reported that growth regulator and etiolation treatments were significantly effective in inducing roots in ringed stem cuttings of *A.marmelos*. An invigoration treatment (the production of water shoots following removal of large branches) accompanied by growth regulator and etiolating treatment significantly increased root quality of cuttings. The highest rooting rates of 75-80% were achieved by

using 5000 ppm IBA, etiolation and invigoration. Rooting rates of 45 % and 40% can be obtained with the application of 100 ppm IBA and 100 ppm IAA, respectively. It was observed that tip cuttings of bael rooted well under intermittent mist and treatment with IBA at 5000 ppm produced 100% rooting.

Layering

Air layering is very successful in bael provided that mother trees are given invigoration treatment by heading back to few of the thick branches during April. Air layers are prepared in the second week of August by bark ringing and application of IBA at 10,000 ppm in lanolin paste.

Micro propagation

Recently, micro-propagation techniques have also been found successful in bael. True to type and disease free plants can be generated from very small piece of plant in aseptic condition in artificial growing medium rapidly through out the year. Regeneration from explant nucellus (Hossein *et al.,* 1993) and cotyledons leaf (Islam, 1993). Multiplication of shoots can be done by using micro shoots. Arumugam and Rao (1996) reported that cotyledonary node explants excised from 15-days old seedlings of bael were placed in M S medium supplemented with BAP [benzyladenine], IBA IAA or NAA. BAP induced the best production of multiple shoots and subsequent plant regeneration. Rhizogenesis of shoots was achieved in the presence of IAA (Varghese *et al.,* 1993). Elongated shoots were rooted on half strength M S medium supplemented with 0.1mg IBA litre^{-1}(Islam *et al.,* 1993). Maximum survival (90%) was recorded when medium was supplemented with 0.5 mg/l BAP and 0.5-1.0 mg/ l kinetin from the plantlet regeneration from axillary bud. Similarly, maximum number of shoots (4.70) was developed in culture flask containing M S medium supplemented with 2.0 mg/l BAP and 1-0 mg/l kinetin (Bhargava *et al.,* 2008).

Effect of bud wood storage on graft success

Results of study on bud wood storage on graft success revealed that the scion shoots wrapped with news paper 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 under hot semi-arid ecosystem of western India.

Progeny trees/mother plants

The bud sticks/graft wood should always be taken from healthy and true to type progeny trees of commercial / new varieties, which are free from viruses, disease and pest occurrence.

Care of nursery plants

Bael plants at nursery stage are likely to be damaged by frost under north Indian conditions and by scorching sun and hot desiccating wind under hot semi-arid ecosystem of Western India. So, the nursery beds should be covered with thatches made of *sarkanda*, shaded net etc. The beds should be irrigated whenever there is danger of frost. During summer, the irrigation should be given at 2-5 day intervals depending upon agro-climatic condition. A light application of Calcium Ammonium Nitrate or Ammonium sulphate is also recommended to encourage the growth of plants. The beds/ polybags should be kept free from weeds by regular weeding/hoeing. In western India, plants should be irrigated in the morning and evening and should be protected from shaded net to protect the plants from direct sunlight and wind. Weeding should be done properly so that plant could not compete for nutrient during active growth period.

Top working

The old and uneconomic bael tree can be turned into an economic and vigorous one by top working. In this method, bael trees should be cut back to 3-4 feet from the ground in month of March and new healthy shoots arising from the stump should be allowed for further growth. Patch budding on these shoots should be performed with improved varieties scion in the following June. The trees started fruiting in three to four years. Bud wood should be taken from 1-2 months old shoots. Flowering and fruiting in vegetatively propagated plants begin after three to four years and full bearing can be attained in about 8-10 years under hot semi-arid ecosystem of western India. Seedlings take a longer time to commence fruiting. Singh (1963) reported that the unproductive tree can be transformed into superior and remunerative tree by cutting back the tree at 4 feet in the month of June from ground level and the newly emerged shoots can be budded in June with improved scion.

Agro techniques

Orchard establishment

The land may be prepared by usual ploughing, harrowing and levelling. There should be gentle slope to facilitate proper irrigation and proper drainage to avoid the harmful effects of water stagnation during rainy season particularly in black cotton soil. Well-decomposed organic matter is mixed with soil and pits are filled. Planting is done during rainy season when the soil in pits has already settled. While planting, one should be careful that the earth ball does not break and graft union remains well above the ground level. Soil all around the stem should be pressed properly to avoid the formation of air pockets. The plants should be irrigated immediately after planting. In the initial 2-3 years, it is advised to protect plants against low and high temperature injury and from hot

desiccating winds by covering plants with some short of cover, leaving the one side open. Shelter belt and wind breaks around the orchard protect the tree from hot desiccating wind during summer. For this, 2-3 rows of fast growing drought hardy tree species should be planted in staggered manner. In India, bael is planted at the distance either 8m x 8m or 10 mx10 m. No systematic work has yet been taken up on nutritional requirement of bael tree.

Planting

The planting of bael seedling is done at 10m x 10m or 8m x 8m depending upon the agro-climatic conditions. Under rainfed condition of hot semi-arid ecosystem, planting of vegetatively propagated saplings of variety Goma Yashi laving short stature growth can be done at 5m x 5m spacing to maximize the productivity. The pits of 1m x 1m x 1m are dug and exposed for solarization to kill harmful soil organisms, providing better aeration in the future rooting zone and making provision for the nutritional requirement for the healthy development of plants. The pits are filled with top soil mixed with 20-25 kg FYM after drenching with chlorpyriphos @ 3ml/ litre to avoid the attack of termite during early phase of the plant growth. The ideal time of planting under rain fed condition is July. *In-situ* patch budding is found more suitable for orchard establishment under rainfed condition of semi arid ecosystem.

Concept of high density planting system

Orchards having relatively low tree number per unit area on way out and for intensive planting with small trees are in vogue. High density planting not only provide high production and net returns during initial stage of bearing, but also ensures better utilization of resources like land, labour, fertilizers, solar radiation, pesticides and management of weed, which ultimately leads to higher yield. High density planting by adopting suitable planting systems has been viewed as successful in many fruit trees. Considerations of the soil condition, planting geometry and manipulation in the spacing are an important means in obtaining higher productivity per unit area.

Planting system

No proper research has been done on plant geometry of bael orchard. Generally, bael plantation is being done in square system. Seedling of bael is planted on boundary of orchard as wind break. Planting of the bael at 6 m x 6 m in square system and at 5m x7m in rectangle system has been recommended by (Singh and Nath, 1999). The main objective to follow particular planting system is to accommodate the maximum number of trees per unit area without affecting the yield efficiency and fruit quality adversely. Some of the popular systems of planting in vogue are the square, rectangular, quincunx, hexagonal, contour, hedgerow, double hedgerow, paired and cluster planting. In India, most of the farmers are poor and having less resource like land holding, irrigation facility etc., and the high density planting is the suitable to increase the productivity by accommodating more number of plants per unit area.

High density planting

The land area under cultivation is shrinking due to urbanization, fragmentation of land holding and industrialization. In such circumstances, the concept of high density planting has become the need of hour to fulfill the fruit requirement to the people of the country. Basic approaches of high density planting are the availability of dwarfing rootstocks/ intertocks, cultivar and with the use of growth regulators. However, closer spacing, growth regulation by training and pruning, use of mechanical device may be tried for successful adoption of the concept of high density planting. At CHES Godhra, work for the evaluation of high density planting systems has been initiated with variety Goma Yashi which is released by the Institute recently (Singh, *et al.*, 2009).

Irrigation

In general, irrigation is not practised in bael cultivation under rain fed condition, but it promotes better growth during establishment and the early stages of growth, especially during the summer. In the juvenile phase plants require 8-10 irrigations in a year while bearing trees require 4-5 irrigations during the time of fruit development and ripening. In dry areas, the use of water harvesting techniques during the rainy season will be useful for ensuring proper irrigation to improve subsequent growth and yield. In dry areas, the use of water harvesting techniques during rainy season and mulches, organic and inorganic, should be adopted as it encourages subsequent growth, flowering and fruiting of the plant. 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. Drip irrigation or fertigation increases the productivity of optimization of moisture content in the root zone in addition to water saving. Nevertheless, bael can successfully be grown wthout irrigation under rainfed conditions of hot semi-arid evsystum of western India

Mulching

Mulches not only conserve soil moisture but also impart manifold beneficial effect, like suppression of extreme fluctuation of soil temperature, reduced water loss through evaporation, resulting more stored soil moisture, maintenance of soil fertility, suppression of weed growth, improvement in growth and yield. Continuous use of organic mulches is helpful in improving the soil physico-chemical properties, microbial flora and soil aeration which ultimately resulted into better growth and yield of plant. Under rainfed condition, application of organic mulch in tree basin is very beneficial for successful cultivation of bael. It reduces the loss of moisture from the soil, enhances the rate of penetration of rainwater or irrigation in the soil and controls the growth of weed. Mulching can be done with black

polythene or any suitable organic material. Mulching with paddy straw, maize straw, grasses and rice husk reduces the weed population and conserves the moisture in the soil. An organic mulching material improves soil properties like pH and EC. Microbial and earthworm population in the basin soil increases with the use of organic mulch over long period. Mulches should be applied in the tree basin (20 cm thick) after rainy season and un decomposed organic mulches should be incorporated and mixed with soil of tree basin in forthcoming Monsoon. Leaf litter of bael under the canopy is not only effective to retain soil moisture during summer but also improve the soil properties.

Integrated nutrient management

Integrated nutrient management refers to maintain soil fertility and plant nutrient supply to an optimum level for sustaining the desired crop productivity through optimization of the benefits from all possible sources of plant nutrient in integrated management. Therefore, it is a holistic approach, where the first things to know what exactly is required by the plant for an optimum level of production, in what different forms these nutrients should be applied in the soil and at what different timings in the best possible method and how best these forms should be integrated to obtain the productive efficiency of the economically acceptable limits in an environment friendly manner. In soil application method, fertilizers should be applied in active root zone. However, with the advent of drip irrigation system and availability of liquid fertilizers, the nutrient application technology is considered to be the most efficient. Bael, being minor fruit crop, no systematic work has yet taken up on manuring and fertilization. Generally, bael trees are not manured. However, an annual dose of about 20 kg of FYM during the pre-bearing period and 50-80 kg per tree at bearing stage is considered beneficial. It is suggested to apply 10 kg Farm Yard Manure and 50, 25, 50 g N P K, in one year old plant, respectively. This dose should be increased every year in the same proportion up to the age of ten years. Sometimes in rich soils, the trees have a tendency to put on more vegetative growth with the result that the fruiting is delayed. Singh and Mishra (2000) have reported seasonal variation in root distribution pattern of bael.

Diagnosis and Recommendation Integrated System (DRIS) represents to the mineral nutrition of the crop and it has an impact on the integrated set of the norms resulting calibrations of the plant tissue, soil composition, environmental parameters and farming practices as the functions of the yield (Bhargava and Singh, 2001).

The most important advantages of the DRIS approach are its ability to make a diagnosis at any stage of the crop development and to list the nutrient elements in order of importance, which are responsible for limiting the yield. DRIS norms, however, need to be standardized in bael.

Earthworm and microbial population of the basin soil is found to increase with the use of FYM and cakes. The manure and mixture of fertilizer should be spread and incorporated in the soil thoroughly up to the canopy of plants. Foliar feeding is very useful in supplementing nutrients, particularly nitrogen and micronutrients. Three foliar sprays with 0.6% mixture containing zinc sulphate, borax and ferrus sulphate in equal proportion during July, October and November have been found beneficial.

Training

Basically, training is a potential tool to manage the canopy architecture of the plant. In order to avoid difficulty in intercultural operation, framework of branches is allowed to develop above 0.6-1.0 m from the ground level. The plants are trained to straight central stem in which branches are not allowed up to 60 cm. Young plants should be allowed with 4 - 6 well spaced branches in all direction to develop into the main scaffold structure of the tree. Young plants are trained with the help of stake, if needed so that they can grow erect. Suckers appearing from rootstocks should be removed. In order to provide good frame work of individual tree, it is essential not to allow lateral branches near to the ground on trunk.

Pruning

Pruning is a tool to regulate tree size and shape to achieve a desired architecture of the canopy and also to reduce the foliage density by removing the unproductive branches to make the tree open. Generally, bael plant is not pruned once tree starts fruiting, because the branches of such plant are self oriented, even though, in case of rosette growth, few branches should be removed from its place of origin to have well spaced scaffolds. Regular pruning in bael plant is not required because fruiting takes place on new shoots as well as old shoots. However, dried, criss-cross, week and diseased branches should be removed as and when required. It will facilitate easy harvesting of the fruits. Pruning of few growing branches becomes necessary particularly when orchard has been established under high density planting system.

Weed management

Productivity can be increased when all the aspects of production technology including weed management, inter culture operation and inter cropping are given due consideration.

Productivity of bael orchards can be increased by proper weed management. Weeds affect plant growth and yield adversely very slowly in a subtle way. Most weeds although complete their life cycle in a shorter period but compete with plants for light, water and nutrients and thereby reduce the yield. In the orchard, hoeing, hand weeding and ploughing of the land 2-3 times a year are done to suppress the weed growth. Regular spading of basin soil is required to check the moisture loss through cracks developed in summer nearby plant particularly in black cotton soil. In rainfed condition, any vegetable crops grown in rainy season can be taken as intercrop in bael plantation. Intercropping and mulching also help in controlling weeds in tree basin.

Inter corpping

Intercropping is intended to maximize land and space use efficiency to generate supplemental income particularly during the initial unproductive phase of the orchard to protect the interspaces from losses through weeds, erosion, impact of radiation, temperature, wind and water and enriching it by nitrogen fixing legume crops. During the early phase of orchard establishment, interspaces left between tree rows can efficiently be utilized by raising suitable crops which not only enrich the soil but also generate additional income. Compatible crop combination is necessary with regard to species, cultivars, planting method and sequence. Cucurbitaceous (pumpkin, bottle gourd, cucumber, bitter gourd and sponge gourd), leguminaceous (cowpea, cluster bean and gram) crops and okra can be taken as intercrops in the bael orchard.

Canopy management

Canopy management of the crop deals with the development and maintenance of their structure in relation to the size and shape for the maximum productivity and quality. Tree vigor, light, temperature and humidity play a vital role in production of quality fruits. The crux of canopy management lies in fact, as how best we manipulate the tree vigour and maximum use of available sunlight and temperature to increase the productivity and minimize the adverse effect of weather. Pruning is done to improve and regulate tree size and shape to achieve desired architecture of the canopy and also to reduce the foliage density by removing unproductive branches of the tree.

Flowering and fruiting

Generally, flower bud emergence takes place in the month of April and flowering in full bloom stage appeared in the month of May under hot semi-arid ecosystem of western India (Singh *et al.,* 2008c). The seedling tree requires 7-8 years to bear fruits while budded

plants starts bearing fruits at the age of 3 to 4 years after planting and fruits become ready for harvest after 10-11 months or so by March-April in hot semi-arid ecosystem of western India. However, this may vary according to the genotypes and agro-climatic conditions.

Flowering pattern

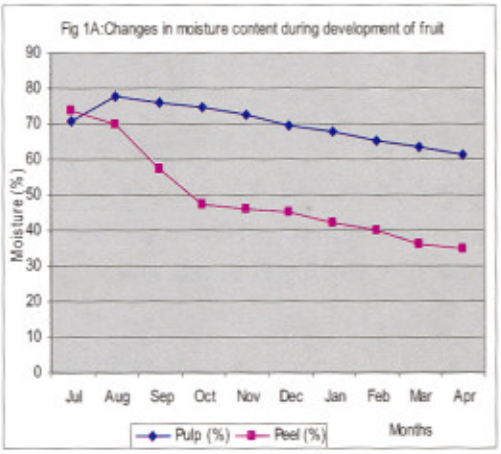
Fruit growth and development

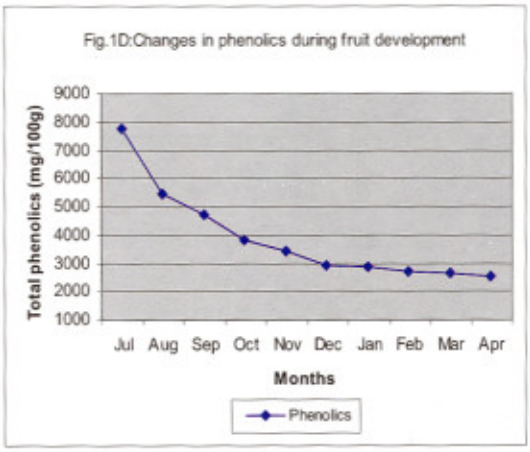
The growth and development of the bael follow a single sigmoid curve. The growth rate of bael has three distinct phases; the initial slow increase for one month followed by rapid increase for three months and then more or less a stationary phase until the fruits are harvested. The moisture content of bael fruit decreases during development and ripening. With the decrease in peel moisture, the hardness of starch appears and increases steadily till harvest, but disappears with ripening (Fig.1A). The rate of respiration in bael fruit at early stage of development is rapid and it declines with growth (Fig.1F). However, an upsurge in respiration is noticed after picking the fruit from the plant. Based on the respiratory studies, the bael fruit can be classified as a climacteric fruit. With the fall in the rate of increase in mucilage, the starch appeared and continued to increase with the development but disappeared while ripening (Fig.1B). The total and non reducing sugars of the fruit show a rising trend during development (Fig.1C).Total phenolics content of the bael fruit decreased during the development and ripening (Fig.1D). The inherent low acidity of the fruit shows decreasing trend during development and ripening (Fig.1E). It has been observed that the bael matures in December-January in Western India. However, the fruit ripens normally only in March-May. Studies on biochemical changes in fruit and reported an increasing trend in both reducing and non-reducing sugars. Fruit pulp contained very low acid levels which did not vary much with fruit development. The ascorbic acid content increased with fruit maturity. A sharp increase in pectin, tannin and marmelosin contents in the pulp was recorded until January and thereafter a gradual decline was noticed (Roy and Singh, 1980; Pande *et al.*, 1986).

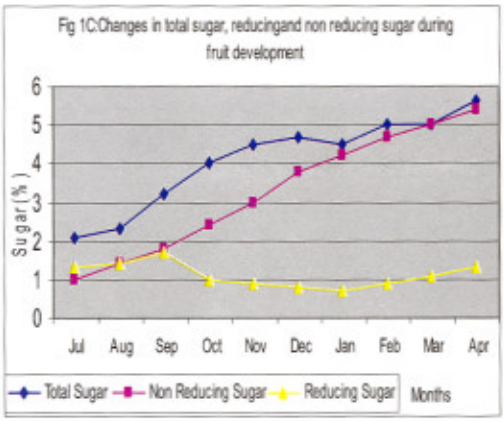
Fruits at maturity

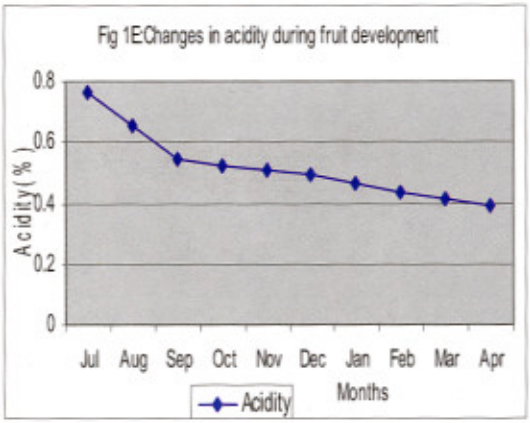
There is a progressive fall in crude protein content during fruit development. However, a slight increase is noticed during ripening. The pectin expressed as calcium pectate increase during development and ripening of bael fruit. It has been observed that the bael fruit matures in December-January under rain fed conditions of western India. However, the fruit starts ripening from March onwards under rain fed conditions of hot arid ecosystem of western India.

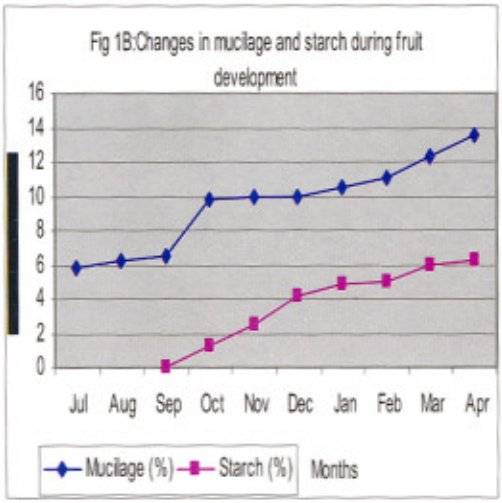
Fig.2.Changes during development of bael fruit under rainfed conditions of semi arid ecosystem.











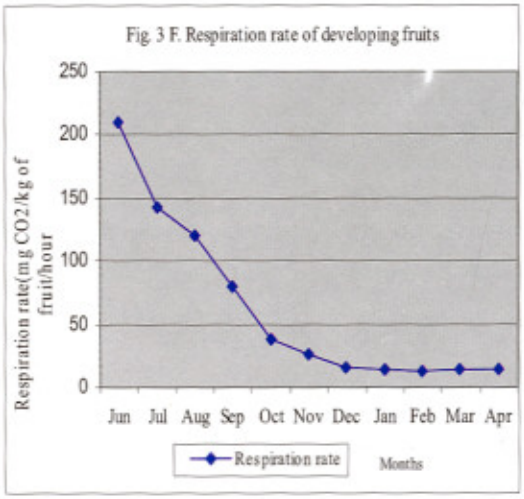


Table 6: Monthly morphological characters of bael fruit during growth and development under rain fed conditions of hot semi-arid ecosystems of western India

Period after fruit set	Characteristics of the fruit
June	Rind deep green and soft, no seeds, flesh become brown rapidly after exposure
July	Rind deep green, soft and easily peeled, flesh slightly light yellow, turns brown on exposure, small soft seeds and very thin mucilage noticed.
August	Rind deep green, hard, difficult to peel, flesh light yellow; seed soft, size increased, mucilage thin
September	Rind deep green, very hard, impossible to peel, flesh light yellow; seed little hard, kernel formation noticed, mucilage fairly thin and cavity is full of seeds and mucilage.
October	Rind green, very hard and woody, flesh yellow, seeds hard and hairy, mucilage fairly thick, kernel prominent
November	Rind green. very hard and woody, flesh yellow, seeds very hard and hairy on surface, mucilage thick, kernel prominent
December	Rind slightly light green, very hard and woody, flesh deep yellow, seeds very hard and hairy on surface with complete formation of kernel, mucilage thick
January	Rind light green, very hard and woody, flesh deep yellow, seeds very hard and hairy on surface with complete formation of kernel, mucilage thick
February	Rind greenish yellow, very hard and woody, flesh deep yellow, seeds very hard and hairy and mucilage thick
March and April (Fruit harvested)	Rind yellowish green, hard and brittle, flesh texture soft, prominent flavour of ripeness appeared, seeds very hard and hairy on surface with complete formation of kernel, mucilage thick
Fully ripe stage (8-15 days)	Rind yellowish, pronounced ripe fruit flavour, pulp sweet and soft, fruit detaches easily from the stem end.

Pest and diseases management

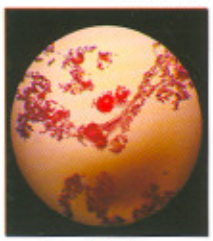
Pests

Generally, bael is free from serious pests and diseases, but the insect pest damage the crop considerably, especially when environmental conditions are very conducive. Termite attack on new saplings is a major problem. Application of chlorpyriphos @2-3 ml / litre /plant has been found effective to control the termite. Chafer beetles or leaf eating caterpillars cause damage to the plant and it can be controlled by 2-3 sprays of dimethoate @1.5-2.0 ml/ litre at 15 days interval.

Diseases

A new leaf spot disease of bael caused by *Fusarium roseum* Link has been reported by Kore and Dhande (1973). Bacterial shot-hole and fruit canker of bael are caused by X*anthomonas bilvae*. The symptoms on the leaves are characterized by round, water soaked spots (0.5 mm) surrounded by a clear halo. Gradually, the spots increase in size (3 mm to 5 mm) and form brown lesions with saucer-like depression in the centre surround by oily raised margin. The primary localized lesions all over the leaf are always followed by falling-out of the necrosed tissues leaving circular or slightly irregular perforation of shot holes. The pathogens also infect the fruit, twigs and thorns. The disease can effectively be controlled by 2-3 sprays of 500 ppm streptomycin at 15 days interval.

Fruit rot *(Aspergillus nidulans)*



A. nidulans

Internal rotting of fruit is a serious problem, which is mainly caused by damage to fruits during harvesting, storage and transportation or Maintain proper ventilation during storage. Avoid storage in enclosures especially in polythene. Such disease problems can be avoided by harvesting of fully mature fruits and also to avoid damage to the fruit and wrapped/stored with newspaper or phenol papers.

Rotted fruit

Physiological Disorders

Fruit cracking

The fruit cracking has been observed as a major physiological disorder and its degree of damage depends according to genotypes/varieties and locality. The fruit cracking takes place twice in a year *i.e* winter season (December-January) while

developing fruits are immature ii) during summer season (March-April) when fruit are mature and in ripening phase. The cracking at later stage is more severe than former one. The cracking can be minimized by maintaining optimum soil moisture regime and by provision of wind breaks against hot desiccating wind side of orchard. Organic mulches like paddy straw, maize straw, *subabul* loppings can effectively be utilized in maintaining soil moisture of tree basin particularly during summer under rain fed conditions of hot semi-arid ecosystem (Saini, *et al*, 2004).

Fruit cracking

Fruit drop

Fruit drop is a natural phenomenon, but its extent of damage is a matter of concern. The extent of fruit drop varied according to genotypes/ varieties and locality. Immature fruit drop (marble size) has also been observed. Sometimes ball size fruits also fall down. The extent of fruit drop in bael can be reduced effectively by adopting better orchard management practices and application of growth hormones like NAA (15-20 ppm / litre).

Harvesting

Bael fruits are likely to get damaged if proper care is not taken during harvesting. The tree is in leafless condition during harvesting particularly in late maturing varieties while early maturing varieties do not shed their leaves at the time of harvesting under rainfed conditions of semi-arid ecosystem of western India. Mature bael fruits are harvested individually from the tree along with the portion of fruit stalk (2-3 cm) to avoid infection and it also helps to judge the ripening. Harvesting by shaking of trees should be discouraged, as the fruits are likely to develop cracks on impact as the peel of fruit is highly brittle which invites infection and can cause heavy loss during storage.

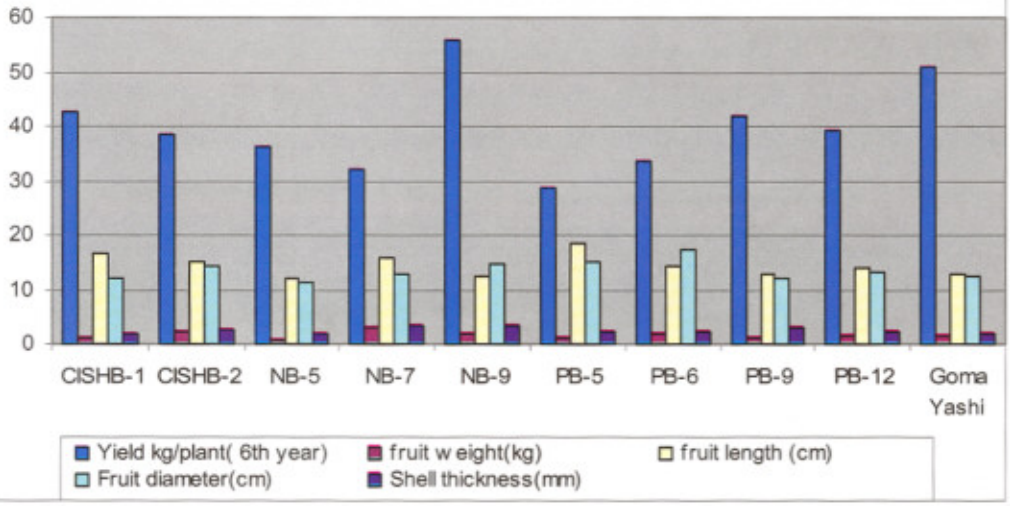
Bael tree with ripening fruits (Defoliated condition)

Yield and yield attributing characters

The number of fruits per tree may vary from 30-45 at the age of 6-7 years depending on genotype, soil and climatic condition. However, a seedling tree at the 30-40 years age can yield 500-800 fruits. Physical characters of fruit in terms of fruit size, fruit weight, shell thickness varied in different varieties/genotypes. (Fig. 2A).

Harvested mature fruits

Fig2A: Yield and yield attributing characters of bael varieties



Ripening

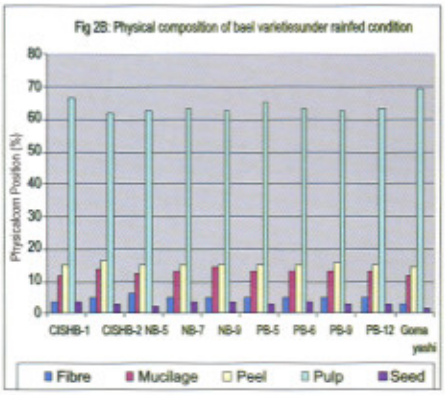
Fruit setting in bael takes place in early May and ripe fruits are available in the following March-June. However, this may vary in different agro-climatic zones of the country. The stalk is easily separated while pressing the fully ripened fruit which is indication of ripening. Proper care is required for harvesting of bael fruits. Ripening of bael fruit can be accelerated by combination of high temperature and exogenous application of ethylene. It has been found that ethylene induced ripening is not effective at lower temperature. Fruit treated with 1000-1500 ppm with ethrel and keeping at 30^0_C after harvesting can be made available 2-3 months ahead of schedule time of ripening. It takes 18-24 days for the fruits to be artificially ripened. The composition of bael fruit, whether ripened artificially or naturally, does not vary much; the sugar accumulation

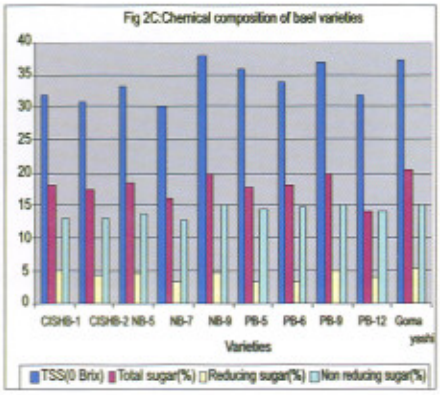
Ripening fruits

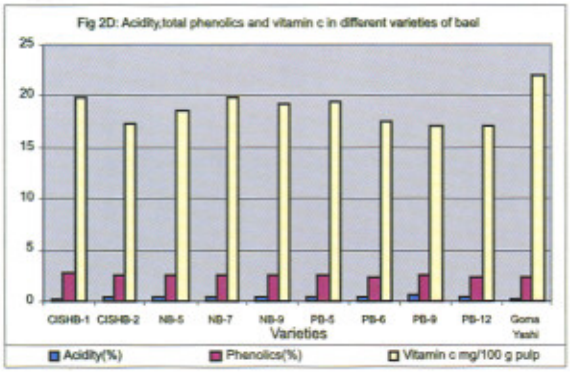
in natural ones is slightly more than artificially ripened. The specific gravity of the bael fruit is initially high, which falls gradually up to 3 months and thereafter it increase and remains more or less constant. Considerable loss in specific gravity is noticed at the time of ripening. No climacteric rise in respiration is noticed as long as the fruit is attached to the plant. However, rapid upsurge in fruit respiration, total and reducing sugar and decline in moisture, phenolics and acidity has been observed after harvesting the fruit till complete ripening which coincides with the optimum ripening condition of fruit (Roy and Singh (1981). Under rain fed conditions of hot semi-arid ecosystem of Western India monthly observations on the morphological characters of bael during development and ripening are given in Table-6.

Quality attributes

Results of study on the varieties evaluated for their quality attributes revealed that the physico- chemical attributes differed significantly among the







evaluated varieties. The physical composition in terms of peel, pulp, mucilage, fibre and seed per cent in fruits (Fig.2B) and chemical composition, *i. e.* TSS, total sugar, reducing and non reducing sugar, acidity, phenolics and vitamin C content varied in

the different varieties(Fig.2 C & D). Differences in physico-chemical characters in the bael genotypes have been reported by Teaotia *et. al.*(1963), Jauhari *et. al.* (1969), Mazumdar (1975), Pandey, *et. al.* (1986), Ram and Singh, 2003, Singh *et. al.*(2000) and Singh *et. al.* (2008d)

Grading and packaging

Bael fruits have different shape and size; hence they should be graded accordingly. At the time of harvest, generally but not always, the tree is in leafless condition at the time of harvesting and the fruits are completely exposed particularly in late maturing cultivars/genotypes. There is no recommended practice for packing bael fruits. At present, the fruits are packed in gunny bags, baskets or wooden crates and sometimes they are transported without any packaging. However it is essential that some cushioning material namely, straw paper, saw dust, news paper liner etc. should be used while packing bael fruits. The fruit should not develop any crack or damage during packing, transportation, marketing and storage; otherwise it may cause spoilage by fungal infection.

Storage

Fruits harvested at full maturity for preserve making can be stored up to 15 days and fruit harvested at ripe stage can be stored up to 7-9 days at room temperature. Fruit can be stored up to three months at about 9°C and 85-90 per cent humidity under cool storage. It is sensitive to low temperature injury like other subtropical fruits. At low temperature, spoilage is caused mainly due to chilling injury, *i.e.* appearance of brown spots on the fruit surface during storage below 8-9°C while at high temperature, spoilage is mainly due to fungal attack. During storage, an increase in total sugars and greater accumulation of reducing sugars are observed.

During storage of bael fruit products, there is reduction in non-reducing sugars and increase in reducing and total sugars. Addition of SO_2 not only improves the initial quality of the bael fruit slab, toffee and powder, but also prevents non-enzymatic browning reaction during storage of all the bael fruit products. The optimum relative humidity for the storage of bael fruit slab, toffee and powder is found to be 63, 58 and 5 per cent, respectively. Practically no change in organoleptic quality is noticed in frozen pulp after six months and in case of other products stored at 37°C, the organoleptic quality remained up to acceptable point (Roy and Singh, 1979d).

Processing

Bael fruit is not popular as dessert fruit due to its hard shell, mucilaginous texture and numerous seed and fibre content. Bael fruit has been used widely from time immemorial for processing in the mature green form to prepare preserves, but recently methods have also been standardized to process the ripe fruit. Roy and Verma (1950) mentioned the process of manufacturing bael squash and bael jam. In the same year Agnihotri (1950) published the method for preparing and preserving syrup from ripe fruits. However, an early report of Singh and Dutt (1941) stated that although the fruit is rich in pectin, even though it can not form jelly due to the excess of gummy substances. Verma and Ahmed (1958) reported that bael fruit powder could also be manufactured successfully. Fruits can be processed into number of acceptable products like slab, powder, toffee, squash, jam RTS etc. which are briefly mentioned below in flow chart.

Flow sheet chart of various value added products of bael

Flow chart of Preserve

Pulp graded + Washed mature green bael fruits→ Break fruits →Scoop out pulp along with seeds and fibres→ Discard seeds→ Cut pulp in 2.5 cm thick slices→ Wash in water →Prick with a fork→ Soak overnight in cold water→ Blanch→ Prepare 40% sugar solution →Impregnate with sugar by gradually raising the syrup to 78°Brix →Pour into jars and seal

Flow sheet for extraction of bael fruit pulp

Ripe bael fruit →Washing→ Breaking→ Scooping of pulp with seed and fibre (Discarding) →Addition of water equal to the weight of pulp→ Addition of citric acid (Titratable acidity 0.5%) →Kneading →Heating at 80° C for 1 minute →Passing through a pulping machine or stainless steel sieve of 20 mesh (Discarding seeds and fibres) →Bael fruit pulp →Canning

→Freezing

→Preserving by SO_2

Flow sheet for slab

Bael fruit Pulp→ Addition of sugar (100 g per kg of pulp)→Heating →Cooling and addition of SO_2 (1 g per kg of pulp) →Traying →Drying at 55-60° C for 15-16 hours to a moisture content of 14.5% →Cutting →Packing.

Flow sheet for toffee

Bael fruit pulp→ Concentration of pulp to a third of its original volume→ Mixing of milk powder, sugar, glucose and fat according to recipe → Cooking → Addition of SO_2 → Mixing→ Rolling into sheets → Cooling and cutting → Drying at 55-60° C for 5-6 hours to a moisture content of 8.5% →Packing.

Flow chart for squash

Pulp → Dissolve citric acid (25g/kg) in water and add → Dissolve potassium meta bisulphite (2.5g/kg) in water and add → Filter and add → Prepare syrup by mixing 1.41 water and 1.6kg sugar per kg of pulp →Mix →Pour into bottles and seal →Heat pasteurize in bottles at 80-95°C →Cool in cold water

Flow sheet for powder

Bael fruit pulp →Addition of SO_2 (1g kms per kg of pulp) →Traying→Drying at 55-60° C for 17-18 hours to a moisture content of 10% →Cutting →Further drying at 55-60°C for 9-10 hours to a moisture content below 4% →Grinding →Packing

Flow chart of Jam

Pulp → Mix 1 kg sugar and 10g pectin per kg pulp and add → Heat mixture while stirring until weight of pulp is reduced to half →Dissolve citric acid (5g/kg) in water and add →Continue cooking until total sugar content is 68.50% →Pour into jars and seal →Cool at room temperature

Flow sheet RTS

Bael fruits (Ripe) → Breaking of shell → Removal of pulp with seed and fibre→ Addition of water (1: 1) →Mixing of pulp with water →Passing through the pulper→ Pulp →Mixing with syrup solution (sugar + water + acid) according to recipe→ Homogenization → Addition of preservative → Bottling → Crown corking→ Pasteurization → Cooling → Storage

Export potential

Bael fruit has good storage capacity and it can be transported to distant places easily. It has tremendous scope for processing. Value added products can be exported to earn foreign exchange. Bael fruit powder has also immense potential in the global market.

Socio - economic considerations wasteland utilization

Bael can endure unfavorable agro-climatic conditions and thus it is suitable for rehabilitation of various types of wastelands. Thus, by their growing, dry lands, wartelands, infertile soils can be made productive for producing additional food and nutritional security to the poor and marginal farmers. Important aspect of fruit is therapeutic and nutraceutical value, which could safeguard stomach ailments and improve health of rural population.

Future research needs

Bael is a fruit attaining importance due to suitability to various types of wastelands and having high therapeutical and nutraceutical properties. Still, a lot have been remained to do for popularization of this crop. Bridging the research gaps will be helpful for its wide spread for commercial cultivation and increased production in the country. Some of the research gaps have been identified which are as under:

1. A wide range of genetic diversity is available throughout the country especially in the states of U. P., Bihar, Uttarakhand, Jharkhand, Chhattisgarh, M.P. Gujarat etc. Existing elite genotypes needs to be exploited for improvement.
2. Fruit drop and cracking of fruits are the major problems of bael cultivation. To overcome these problems, varieties having high yield potential and better qualitative characters and free from these disorders should be developed.
3. Development of varieties which have less seed and fibre and have more TSS, vitamins etc.
4. Emphasis should be given on post harvest technology to develop value added and export oriented processed products. Small scale processing units should be established and promoted for commercialization of this fruit crop.
5. Screening of genotype for abiotic especially drought resistant and moisture stress and biotic stress is essential and characterized them for various agro- climatic conditions.
6. Development of integrated crop management strategies for sustainable fruit production of bael.

7. Development of suitable varieties for high density orcharding.
8. Bael based cropping systems and cropping models should be developed to provide stability in income to the farmers.

Bibliography

Agnihotri, B. N. (1950). The Bael (*Aegle marmelos* Correa.) *Indian Fd. Packer*, 4 (9): 29-31.

Aiyer, A. K. Y. N. (1956). *The antiquity of some field and forest flora of India*. Banglore Printing and Publishing Co. Ltd., Banglore.

Anon. (2001). *Annual report*, AICRP on AZF, CIAH, Bikaner

Arumugam, S. and Rao, M. V. (1996). *In-vitro* production of plantlets from cotyledonary node cultures of *Aegle marmelos* (L.) Corr. *Adv. Plant Sci.*, 9 (2): 181-186.

Banerjee, N. and Maiti, M. (1980). Some physico-chemical studies on a protein rich fruit seed (*Aegle marmelos* Correa.) *J. Indian Chem.* Soc., 57 (9): 945-946.

Bhargava, B. S. and Singh, R. (2001). Leaf nutrient norms in fruit crops. *Indian J. Hort.*, 58 (1-2): 41-58.

Bhargava, R. Kumar, R. Chauhan, S., Singh, R. S., Sharma , B. D. and More, T. A.(2008). Establishment of contamination free culture in bael (*Aegle marmelos* Correa). *Indian J. Arid Hort.*(Accepted).

Chadha, K. L. (2001). *Bael. In: A handbook of Horticulture*, ICAR, New Delhi.

Chakraborty, D. P., Bhattacharyya, P. and Chattopadhyaya, K. K. (1978). Marmelida, a tyrorinase accelerating and tryptophan pyrrolase inhibitory juranocumarin from *Aegle marmelos* Correa. *Chem. Industr.* 2: 848.

Chatterjee, A. and Choudhury, B. (1960). Occurrence of auroptene, umbelliferone, marmine, lupel and skimmianine in the root of *Aegle mermelos* Correa. *J. Indian Chem. Soc.,)*37: 334-336.

Chatterjee, A. and Bhattacharya, A. (1959). Isolation and costitutiin ofmarmin, a new coumarin from *Aegle marmelos*. *J. Chem. Soc.*, June: 1922.

Chatterjee, A. and Roy, S. K. (1957). Agelenine, a new alkaloid of leaves of *Aegle marmelos*. *Sci. Cult*, 23: 106-107.

Chattopadhyay, R. K. and Mahanta, S. K. (1989). Media requirement for seed germination and seedling establishment. *Indian Hort.*, 36(3):27.

Dixit, B. B. L and Dutt, S. (1932). The constitution of marmelosin. *J. Indian Chem. Soc.*, 9: 271-79.

Gopalan, C. B. N. Rama Sastri and Balsubramanian (1961). Nutritive Value of Indian Food. I.C.M.R, Hyderabad, India.

Haskar, C.N. and Kendurkar, S. G. (1961). Uses of bael gum. *Printindia,* 11 (1): 135.

Hays, W. B. (1957). Fruit growing in India. Kitabistan Allahabad, India

Hossain, M., Karim, M. R., Islam, R. and Joarder, O. I. (1993). Plant regeneration from nucellar tissues of *Aegle marmelos* through organogenesis. *Pl. Cell Tissue Org. Cult.*, 34 (2): 199-203.

Islam, R., Hossain, M., Joarder, O. I. and Karim, M. R. (1993). Adventitious shoot formation on excised leaf explants of in-vitro grown seedlings of *Aegle marmelos* Corr., *J. Hort. Sci.*, 68 (4): 495-498.

Jauhari, O. S. and Singh, R.D. (1971). Bael-valuable fruit. *Indian Hort.* 16 (1): 9-10.

Jauhari, O. S., Singh, R. D.and Awashi, R. K. (1969) Survey of some important varieties of bael (*Aegle marmelos* Correa). *Punjab Hort. J.*, 9: 48-53.

Johns, L. and Stevenson, V. (1979). *The complete book of fruit.* Anqus and Roberson Publications.

Kirtikar, K. R. and Basu, B. D. (1935). *Indian medicinal plants*, Vol-I Published by L. M. Basu, Allahabad.

Kore, S. S. Dhande G. W. (1973). A new spot of bael (*Aegle marmelos* Correa) caused by *Fusarium roseum* Link from India. *Punjab Rao Krishi Vidyapeeth Res. J.*, 1 (2): 223-24.

Kumar, D., Pathak, R. K and Ali, W. (1994). Studies on the effect of duration and methods of budding in bael. *Indian J. Hort.*, 15 (2): 127-129.

Maiti, C. S., Nath, A. and Sen, S. K. (1999). Studies on the propagation of bael (*Aegle marmelos* correa) by different grafting methods in West Bengal. *J. Applied Hort.*, 1(2): 131-32

Majumdar, C. P. (1935). *Upvana-Vinoda (A sanskrit literature on arborihorticulture)* Published by The Indian Research Institute, Calcatta.

Mazumdar, B. C. (1975). Physio-chemical analysis of some types of bael (*Aegle marmelos* Correa).I. Fruits growing in west Bengal. *Indian Agric.*, 19 (3): 295-98.

Mishra, K. K. and Jaiswal, H. R. (2001) Effect of scion genotypes on patch budding in bael (*Aegle marmelos* Corr.). *Adv. Hort. Forestry*, 8: 61-66.

Moti, D. L. and Chaturvedi, O. P. (1976). Propagation of some tropical and subtropical fruits by budding. *Punjab Hort. J.*, 16 (1-2): 33-38.

Om, Prakesh (1961). *Food and drinks in ancient India*. Munshi Ram Manohar Lal. Orient Book Sellers and Publishers, Delhi.

Pal, M. and Mishra, K. K. (2005). Effect of pollen on fruit set, fruit drop and final fruit retention in self-and cross pollination in bael (*Aegle marmelos*). *Indian J. Agric. Sci.*, 75(12): 800-804.

Pandey,N. C., Singh, A. R., Maurya, V. N.and Katiyar, R. K.(1986). Studies on bio-chemical changes in bael (*Aegle marmelos* Correa) fruit. *Prog. Hort.*, 18 (1-2): 29-32.

Parikh, V. M., Ingle, T. R. and Bhide, B. V. (1958). Studies in carbohydrates. Bael fruits (*Aegle marmelos*) mucilage. *J. Indian Chem. Soc.*, 35: 125-29.

Patra, A. Mukhodhyay, A. K., Ghosh, A. and Mitra, A. K. (1979). Composition of *Aegle marmelos*. Carbon-13 NMR spectra of aurapten and marmin. *Indian J. Chem.* 17 (4): 385-387.

Ram, D. and Singh, I. S. (2003). Physico-chemical studies on bael (*Aegle marmelos* Correa) fruits. *Prog. Hort.*, 35 (2): 199-201.

Ray, D. P. and Chatterjee, B. K. (1996). Effect of different concentrations of growth regulators, etiolation and vigoration treatment on the rooting of stem cuttings of bael (*Aegle marmelos* Correa). *Orissa J. Hort.*, 24 (1&2): 36-41.

Reuther, W., Webber, H. J. and Batchlor, L. D. (1967). *The citrus industry*, University of California, Division of Agricultural Sciences. Vol-I: 407-409.

Roy, R. S. and Verma, U. P. (1950). Bael products. *Indian. Fd. Packer*, 14(8): 13-14.

Roy, S. K. and Singh, R.N. (1979 d). Preliminary studies on storage of bael fruit (*Aegle marmelos* Correa). *Prog. Hort.*, 11(3):21-28.

Roy, S. K. and Singh, R. N. (1979 a). Studies on utilization of Bael fruit (*Aegle marmelos* Correa.) for processing II. Extraction of bael fruit pulp. *Indian. Fd. Packer,* 33 (1): 5-9.

Roy, S. K. and Singh, R. N. (1980). Studies on changes during development and ripening of bael fruit. *Punjab hort. J.*, 20 (324): 190-97.

Roy, S. K. and Singh, R.N. (1981). Studies on induced ripening of bael fruit (*Aegle marmelos* Correa). *Punjab Hort. J.*, 21 (120): 74-82

Saini, R. S. Singh, S., and Deswal, R. P. S. (2004). Effect of micronutrients, plant growth regulators and soil amendments on fruit drop, cracking and quality of bael (*Aegle marmelos* Corrrea) under rainfed conditions. *Indian J. Hort.*, 61 (2): 175-76.

Shoeb, A., Kapil, R. S. And Popli, S. P. (1973). Coumarins and alkaloids of *Aegle marmelos*. *Phytochem.*, 12 (8): 2071-72.

Shukla, S. K. and Singh, G. N. (1996a). Seed germination and growth of bael (*Aegle marmelos* Correa.) seedlings as influenced by soil sodocity. *J. Tropical Forestry,* 12 (4): 293-294.

Shukla, S. K. and Singh, G. N. (1996b). Nutrient imbalances in bael (*Aegle marmelos* Correa) leaves as induced by salinity and sodicity. *Indian J. Plant physiol.*, 1 (4): 293-94.

Singh A. K., Singh, Sanjay, Appa Rao, V. V., Hiwale, S. S., Bagle B. G. and More T. A. (2008d). Evaluation of bael varieties under rain fed conditions of semi arid ecosystem. National seminar on opportunities and challenges of arid horticulture for nutrition and livelihood, organized by Indian Society of Arid Horticulture, Bikaner, CIAH, Bikaner, during 08-09 March, pp.78.

Singh A. K., Singh, Sanjay, Bagle, B. G. and More, T. A. (2008b). Evaluation of bael genotypes under semi-arid environment of western India. Paper presented in Third Indian Horticulture Congress on New R & D initiatives in horticulture for accelerated growth and prosperity, organized by The Horticultural Society of India, New Delhi, during 06-09 November, Bhubaneswar, pp. 79.

Singh, A. K., Singh, S., Joshi, H. K., Bagle, B. G. and More, T. A. (2008c). Evaluation of bael genotypes for growth behaviour and floral traits under semi-arid ecosystem of western India. *The Hort. J.*, 21(30): 140-142

Singh, A. K., Singh, Sanjay, Bagle, B. G. and Dhandar, D. G. (2007). Studies on flower biology of bael (*Aegle marmelos* Correa) under semi-arid ecosystem. Proc. National symposium on production, utilization and export of under utilized fruits with commercial potentialities held at B CKV, Kalyani, Nadia, West Bengal during November 22-24, pp.65-69.

Singh, A. K., Singh, S., Bagle. B. G. More, T. A. (2009). Evaluation of bael varieties under rainfed conditions of semi-arid environment of Western India. International Conference on Nurturing Arid Zones for People and the Environment: Issues and Agenda for the 21st Century held at CAZRI, Jodhpur from 24 to 28 November, 2009, pp. 81.

Singh, A. K., Singh, S., Bagle. B. G. and More, T. A. (2008a).Varietal evaluation of bael under semi arid ecosystem of Western India. National seminar on emerging trends in plant sciences and herbal medicines held at N.D.U.A&T, Kumarganj, Faizabad, U.P. on 17th and 18th march 2008, pp-13.

Singh, A. K. and Mishra, K. K. (2000). Seasonal variation in root distribution pattern in bael (*Aegle marmelos*). *Indian J. Agric. Sci.*, 70 (10): 717-18.

Singh, B. N. and Dutt, S. (1941). Studies on formation of jellies from some Indian fruits. *Indian J. Agric. Sci.*, 11:1006-21.

Singh, L. B. (1954). Propagating bael (*Aegle marmelos* Correa.) vegetatively. *Sci. Cult.*, 19: 485-486.

Singh, L. B. (1961). Some promising selection of bael *A. R. Hort. Res. Inst.* Saharanpur, 111-19.

Singh, L. B. (1963). Top working of bael produces economic crop and earlier too. *Indian Hort.*, 7 (3):11-12.

Singh, R. D. (1989). Studies on bael (*Aegle marmelos* Correa). morphology of flower, anthesis, dehiscence and receptivity of stigma. *Prog. Hort.*, 32: 15-24

Singh, R. S. and Nath, V. (1999). *Anupayogi bhoomi mein-upayogi bael vriksh lagayein. Unnat Krishi*, 38(3):3-8.

Singh, R., Misra, K. K. and Jaiswal, H. R. (2000). Studies on physico-chemical characters of fruits of bael genotypes. *Indian J. Hort.*, 57 (4): 314-317.

Singh, V. R., Pandey, I. C., Upadhyay, N. P. and Prasad, R. S. (1976). Propagation of bael (*Aegle marmelos*) by budding. *Punjab Hort. J.*, 16: 57-59.

Singh, V. P. and Misra, K. K. (2004). Estimation of variability parameters for floral traits and yield in bael (*Aegle marmelos* Correa). *Prog. Hort.*, 36 (2): 253-258.

Singh, R.N. and Roy, S. K. (1984). The bael. DIPA, ICAR, New Delhi.

Srivastava, K. K. and Singh, H. K. (2000). Floral biology of bael (*Aegle marmelos*) cultivars. *Indian J. Agric. Sci.*, 70 (11): 797-798.

Teaotia, S.S., Maurya, V.N. and Agnihotri, B.N. (1963). Some promising varieties of bael (*Aegle marmelos* Correa) of Eastern Districts of Uttar Pradesh. *Indian J. Hort.*, 20: 210-14.

Varghese, S. K, Inamdar, J. A., Kiran Kalia, Subramanian, R. B. Nataraj, M. Ad Kalia, K. (1993). Micropropagation of *Aeglemarmelos* (L.) Correa. *Phytomorphology*, 43(1-2):87-92.

Verma, U. *Fd. Packer*, P. and Ahmed, S. (1958). Drying of bael (*Aegle marmelos* Correa.) pulp. *Indian* 12 (7): 7-9.

भाकृअनुप
ICAR

Central Horticultural Experiment Station
Vejalpur, Panchmahals (Godhra), Gujarat.

Regional Station of

Central Institute for Arid Horticulture, Bikaner
(Indian Council of Agricultural Research)