Current Horticulture 6(2): 52–57, July–December 2018 ISSN: 2347-7377; RNI No.: UPENG03865/24/1/2013-TC

Exploring morphovariations in bael *(Aegle marmelos)*

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Received: January 2017; **Revised:** May 2018

ABSTRACT

Bael (*Aegle marmelos* Correa), an indigenous tree having wide genetic diversity, is found growing in different parts except at high altitude and in cold region of the country. Most of the woody plants produce flowers and fruits on new growth or on young leafy shoots, but a few plants bear fruits on main stems, primary and secondary woody branches. This phenomenon is known as cauliflory. Such flowering and fruiting are also observed in bael germplasm established at field gene bank at CHES, Godhra. It has been noticed that bael produce flowering and fruiting on main stems and primary, secondary, tertiary, fourth and fifth branches, and even on previous and current season's growth of shoots. Simultaneously, it has also been also observed that fruits may appear on first, second, third, fourth, fifth, sixth, seventh and eighth year growing woody stems of bael tree under semi-arid conditions in western India. Therefore, bael is a culiflorous and ramiflorus tree, such type of flowering and fruiting are found in bael, but it is common in bael variety, Goma Yashi and NB-16. Vivipary is of unusual occurrence in bael. Generally, such fruits are not good in taste. If cut exposed, germinated seeds inside the fruits are visible very clearly. High humidity and warm weathers appear to be associated with viviparous fruits in bael. The pollen-grains of bael are found to exert a direct effect on size, shape and styler end cavity of fruits, seeds and speed of development of fruits and on time of ripening of fruits of asexually propagated bael plant. Such effect on fruits may be due to metaxenia effect in bael. Variations in number of petals and sepals, number of leaflets and thorns are also observed.

Key Words: Morphovariations, Culiflory, Flowering, Metaxenia, Vivipary, Ramiflorus

Bael (*Aegle marmelos* Correa), an important indigenous fruit of India, is known since ancient times. It is found growing in Nepal, Sri Lanka, Malesia Pakistan, Bangladesh, Myanmar, Thailand and most of the South-East Asian countries. Because of its status as sacred tree, it is also grown in north Malaya, dry area of Java and to a limited extent in northern Luzol of Philippines and gardens of Egypt, Surinam and Thailand. It is distributed throughout the country, but concentrated area under bael is in eastern parts of Gangetic plains and nearby areas, particularly in Uttar Pradesh, Bihar, Madhya Pradesh, Chhatisgarh and Jharkhand, and it can also be seen growing in West Bengal, Punjab and Odisha. In Gujarat, bael trees are found growing naturally in the forest with great diversity.

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Most of the genotypes available in forest areas of Gujarat having small-sized fruits, but plants growing in temple promise or in courtyard of house having big size fruits were brought by travelers, saints, pilgrims from north India (Singh *et al.*, 2014). In India, bael is being grown throughout the country and is also known by other vernacular names (John and Stevenson, 1979). Om Prakash (1961) found bael in Yajur Veda and also observed that in early Buddhist and Jain literature (C 800 B.C. - C 325 B.C.). In the 'Ramayana' period, 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 'Brihat Samhita' mention had been made of bael fruit, and as the legend goes, in the forest, the 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).

MORTHOVARIATIONS IN BAEL

Cauliflory

Most woody flowering plants produce inflorescences on new growth and or young leafy shoots. A few, however, flower and fruit directly on their trunks or main branches. This phenomenon is known as cauliflory (from the latin words 'stem' and 'flower'), and plants themselves are considered cauliflorous. Many fruits are most interesting examples of cauliflory in fig *(F. auriculata)*, jackfruit *(Artocarpus heterophyllus)*, papaya *(Carica papaya)*, cacao *(Theobroma cacao) and* loquat *(Eriobotrya japonica)* grown in India commercially, whereas brazilian grape trees *(Plinia cauliflora)*, cannonball tree *(Couroupita guianensis)* growing in tropical forest (Armstrong, 1998).

In contrast, no instance of this phenomenon has ever been described in bael. At CHES, Godhra, 190 germplasm have been established in field repository which were characterized for various horticultural traits. The flowers and fruits appeared on trunk, primary, secondary tertiary, fourth, fifth and sixth branches, and first, second, third, fourth, fifth, sixth, seventh and eighth year growth of growing shoots (Fig. 1). Bael is an ideal cauliflorous example of fruit tree. Similar results have been reported by Ullah and Haque (2008) in jackfruit. Generally, cauliflorous blossoms are sturdy and well attached and can withstand in aberrant conditions. The adaptive significance of cauliflory is mainly associated with cross pollination.

Metaxenia

Metaxenia is the effect of pollen-grains on fruit shape and other fruit characters. Metaxenia may able to be used to identify best pollinizer parents to decrease fruit development period and increase yield in mixed cultivar planting. This direct effect of pollen-grains on parts of fruit lying outside the embryo and endosperm is called metaxenia. The simplest and most probable theory to explain metaxenia is that embryo or endosperm or both of them secrete hormones, or soluble substances analogous to them. Probably, no instance of this phenomenon has ever been described in bael earlier. The source of pollen exert a direct effect on size, shape and styler end cavity of fruits, seeds and speed of development, and on time of ripening of fruits (Fig. 3)

Fig. 1. Differen views of cauliflorous woody branches in bael

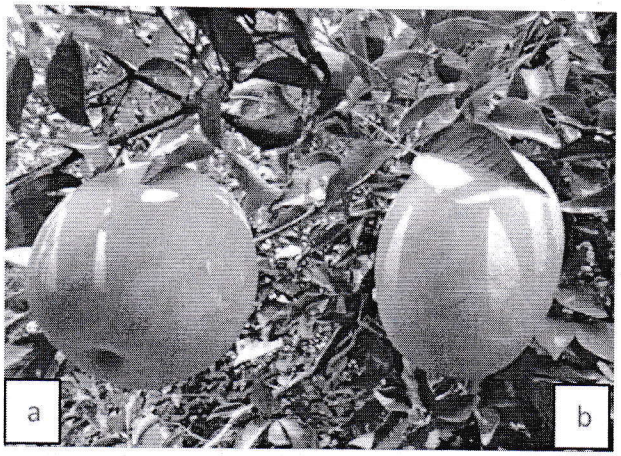

Fig. 2a. Fruit shape affected by pollen-grains (metaxenia) and b: original fruit shape

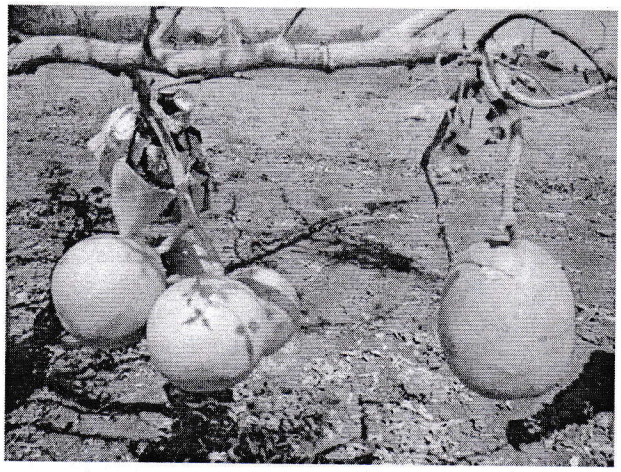

Fig. 3. Effect of pollen on fruit shape and time of ripening

of and quality of fruit of asexual propagated plant (Fig. 2a and b).

This direct effect of male parent on development of fruit is precise and definite and varies with a particular male to fecundate female flowers which diffuse out into tissues of mother plant that constitute seed and fruit, exerting a specific effect on these tissues varying according to a particular male parent used to fecundate embryo and endosperm (metaxenia). The effect of pollen source on fruit development has been reported in several species of different families, including date palm (Swingle, 1928), raspberry (Colbert and de Oliveria, 1990), blueberries (Gupton and Spiers, 1994), pomegranate (Purohit, 1987) and cherimoya (Khan *et al.*, 1994). However, effect of pollen source on sugar accumulation should be carefully examined since pollen source might affect taste qualities of fruit. These results are similar to those reported for dates, cherimoya, grapes and mandarins, in which the source of pollen had an effect on maternal tissue characteristics (Denney, 1992; Wallace and Lee, 1999).

Bael is a cross-pollinated crop. At the time of flowering (May-June), large number of honey bees; beetles, house flies, ants and different kinds of butterflies less in number arrive and start visiting the flowers for foraging purpose (6 AM to 1.0 PM), and they directly enter on central portion of flowers whether it is completely opened or just started to open due to which large number of pollens stick to their abdomen and legs (Fig. 4). Effective pollination occurred through honeybees followed by butterflies. Honeybees have been recognized as ultimate and legitimate pollinators in bael (Singh *et al.*, 2014).

Vivipary

In vivipary, germination of seed takes place inside the fruits while still attached to the mother plant. Viviary is noticed naturally in some species of mangrove like *Rhizophora mangle, R. Mucronata, Bruguiera gymnorhiza,*

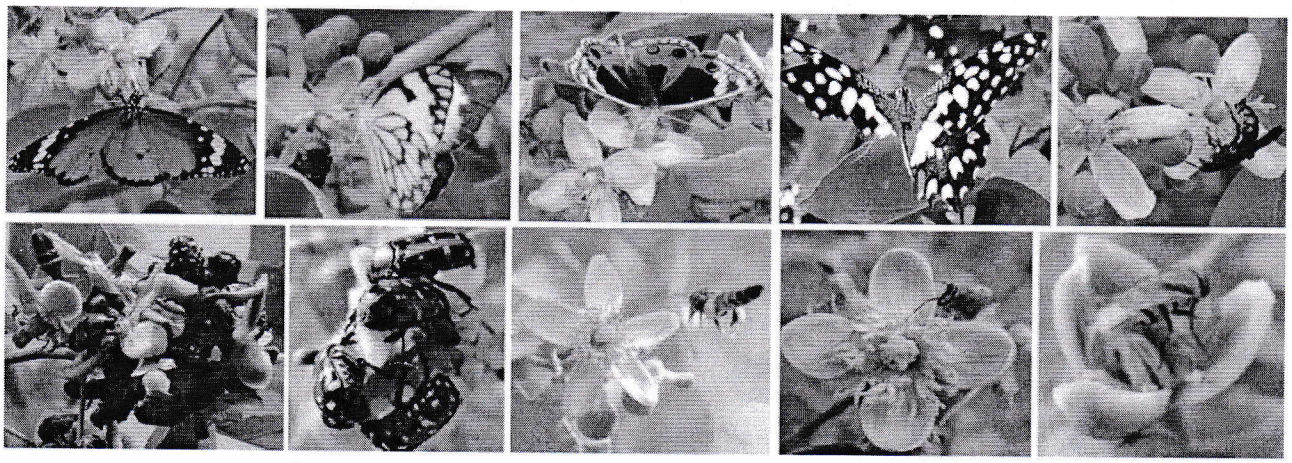

Fig. 4. Pollinating agents in bael

Kandelia reedi, K. candel, Ceriops decandra (all belong to Rhizophoraceae) in which it is considered as an aid to adaptation in wet ecosystem where germinated seeds after falling in mud establish itself and grow as a plant (NHB, 2012). It is very often noticed in *Avicennia* sp (Verbenaceae); *Aegialitis rotundifolia* (Plumbaginaceae); *Aegiceras majus* (Myrsinaceae); *Cocos nucifera* (Arecaceae); *Cucumis melo, Sechium edule* (both Cucurbitaceae plants); *Oryza sativa, Triticum aestivum, Zea mays* (Graminae) *etc*. For most plant species, vivipary is considered undesirable. This holds especially true in cultivated types which are grown mainly for their edible fruits.

Bael fruits as usually remain free from viviparous seeds. Till now, no instance of this phenomenon has ever been described in bael. In contrary, while cutting the fruits for study, an unusual occurrence of vivipary was observed in one of the bael germplasm. The fruit was having a weight of 650 g, its pulp was yellow in colour and was slightly insipid in taste. The cavity formed in fruit pulp were full of amber or honey coloured viscous very sticky or glutinous (mucilage), translucent pulp, which is slightly sweet and feebly aromatic. As appeared physically, it was tree ripen fruits harvested from field gene bank at CHES, Godhra, during 2015. The seeds manifest light yellow coloured radical embedded in mucilage of locule cavity (Fig. 5. a, b and c). Vivipary is considered genetic mutation but its manifestation can be modified by the environment (Stoutmeyer, 1960). Increased precious germination has been reported in susceptible species during wet season (Allard, 1999). The genetics of viviparous mutant has been studied in corn and it has been reported to be associated with nine genes (Libby and Router, 1984). Reduced production or insensitivity of fruit to abscisic acid has also been marked as a feature of vivipary (Hartmann *et al.* 2002). High humidity might play inciting role in expression of vivipary in papaya (Singh, 2013).

Morphological diversity

All varieties of bael showed considerable morphological variation with respect to shape, margin, base and apex of leaf (Singh *et al.*, 2015). Leaves alternate, compound, trifoliate with one pair of shortly stalked opposite showing pulvinus leaflet, ovate or ovate lanceolate, crenate, acuminate and membranous, and midrib prominent beneath which is common in bael. It has also been observed that in place of thee leaflets (trifoliate), in very few leaves, 4-8 leaflets are also found rarely in bael plant emerged directly from root sucker of bael germplasm (Fig. 6). Quantification of total leaflet number is different in different leaves arose from root sucker of single plant of bael. Nicotra *et al.* (2011) reported that different leaf shapes can be found in association with variation in other leaf traits due to different climatic factors.

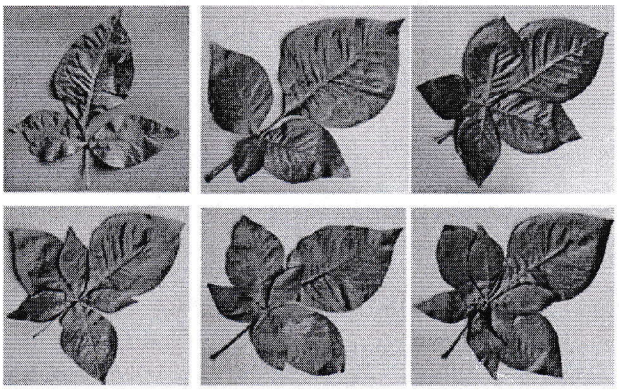

Fig. 6. Variations in leaf morphology

Variation in thorn

Bael tree armed with straight, sharp, axillary thorns, 2-5 cm long. Considerable variation in thorn, its number, size, shape is found in different in different genotypes (Fig. 7). In some of the genotypes, thorn is small and stout, whereas in few genotypes, three thorns can be

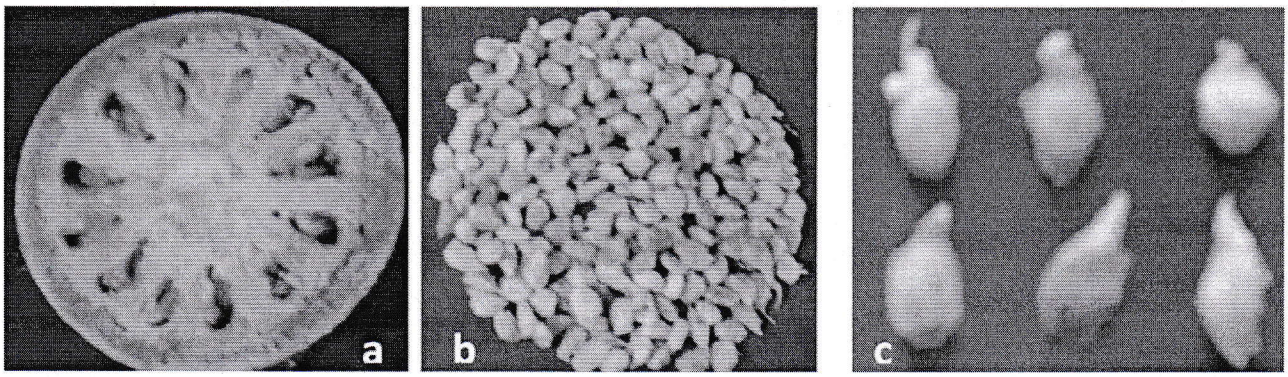

Fig. 5. Transverse section showing viviparous seed, b: vivipery in extracted seed and c. vivipary in individual seed

Fig. 7. Variation in thorn pattern in genotypes under dryland conditions

seen at a node. It can also be observed that the leaf convert into spine in pair in very few genotypes. Generally, two thorns at a node are common. Goma Yashi is thornless under rainfed dryland conditions of western India (Singh *et al.*, 2012). In some of the genotypes, thorn may be seen in primary branches, but not at secondary or tertiary branches under dry land condition. However, it may vary in different agro-climatic conditions (Nicotra *et al.*, 2011).

Variation in flower organs

Bisexual flowers are born in clusters and they are greenish white, axillary or terminal cymes. The calyx is shallow with 4 or 5 short sepals (tetramerous and pentamerous), broad teeth, pubescent outside. Petals are oblong oval, 4 or 5 are common (Fig. 9) and 6 or 7 rarely observed in flower (Fig. 8) and pale greenish white in colour. Stamens are numerous, hypogynous with short filaments. Flower bud emergence, flowering duration, time of anthesis, dehiscence of anther, stigma receptivity and pollen viability vary according to variety and locality (Singhal *et al.*, 2011 and Singh *et. al.* 2014 a and b). Size and shape of floral organs in terms of bud size, flower size, petal size *etc.* of the varieties evaluated at CHES, Godhra under rainfed condition of semi-arid ecosystem according to Singh *et. al.* (2016).

Fig. 8. Flower biology in bael

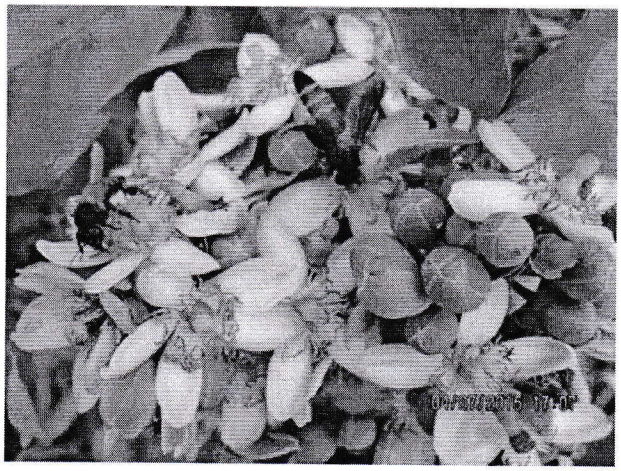

Fig. 9. Four and five petals are common in Goma Yashi variety of bael

CONCLUSION

Thus, it is concluded that bael is cauliflorous and ramiflorous fruit tree, which can bear fruits on any age of shoots. Quantum of flowering, fruit setting and retention varied based on age of woody shoots. Variation in fruit shape and other qualitative characters in fruits of the same mother plant were also observed owing to metaxenia effect. The fruits during ripening may manifest vivipary occasionally. Although, trifoliate leaf is common but 4 - 8 leaflets may also be seen in very few germplasm rarely. Morhpovariation in flower organ, thorn and leaf were also observed.

REFERENCES

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

Allard R W. 1999. *Principles of Plant Breeding*, 2nd edn. New York: John Wiley and Sons.

NHB Gurgaon. 2012. Indian Horticulture Database-2011. National Horticulture Board, Gurgaon, Haryana, p. 4-5.

Armstrong, W P. 1998. The truth about cauliflory. *Zoonooz* **71**: 20-23.

Chaudhary H D, Garhwal O P and Chaudhary M R. 2017. Evaluation of performance of flowerin, fruiting and quality characters of twenty genotypes of ber. *Current Horticulture* **5**: 56-58.

Colbert S and de Oliveira D. 1990. Influence of pollen variety on raspberry (*Rubus idaeus* L.) development. *Journal of Heredity* **81**: 434-437.

Denney J O. 1992. Xenia includes metaxenia. *Hort Science* **27**: 722-28.

Gaithoiliu Phaomei and Lolly S. Parera. 2016. Evaluation of diversity in jackfruit *(Artcarpus heterophyllus)* in Tikrikilla block of west Garo hills (Meghalaya). *Current Horticulture* **4**: 11-15.

Gupton C L and Spiers J M. 1994. Interspecific and intraspecific pollination effects in rabbiteye and southern highbush blueberry. *Hort Science* **29**: 324-26.

Hartman Hudson T, Kester Dale E, Davies Jr. Fred T and Geneve Robert. 2002. *Plant Propagation: Principles and Practices*, 7th edn, Prentice Hall of India Pvt. Ltd., New Delhi, p. 130.

Jain N K. 1991. Antifungal activities of Aegle marmelos Correa, *Indian J. Microbiology* **17**: 51.

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

Kahn T L, Adams C J and Arpaia M L. 1994. Paternal and maternal effects on fruit and seed characteristics in cherimoya *(Annona cherimola Mill.). Scientia Horticulturae* **59**: 11-25.

Libby W J and Router R M. 1984. Advantages of clonal forestry. *Forestry Chronicle.*

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

Nicotra A B, Leigh A, Boyce C K, Jones C S, Niklas K J, Royer D L and Tsukaya H. 2011. The evolution and functional ignificance of leaf shape in the angiosperms. *Functional Plant Biology* **38**: 535-52.

Om Prakesh. 1961. Food and drinks in ancient India. Munshi Ram Manohar Lal. Orient Book Sellers and Publishers, Delhi, pp. 145-49.

Purohit A G. 1987. Effect of pollen parent on seed hardness in pomegranate. *Indian Joumal of Agricultural Sciences* **57**: 753-55.

Singh A K, Singh Sanjay, Singh R S and Makwana P. 2014a. Phenology, floral biology and pollination in bael varieties under rainfed semi-arid conditions of western India. *Indian Journal of Arid Horticulture* **9**: 84-90.

Singh A K, Singh S and Makwana, P. 2015. Intervarietal morphological variability in bael *(Aegle marmelos)* under rainfed semi-arid hot ecosystem of western India. *Current Horticulture* **3**: 3-9.

Singh A K, Singh Sanjay, Makwana P and Sharma S K. 2016. Evaluation of bael germplasm under rainfed semi-arid environment of western India. *International Journal of Noni Research* **11**: 11-19.

Singh A K, Singh, Sanjay, Joshi H K and Singh R S. 2012. Goma Yashi to enrich fruit basket. *Indian Horticulture* **57**: 6-8.

Singh A. K, Singh Sanjay, Singh R S, Joshi H K and Sharma S K. 2014b. Characterization of bael varieties under rainfed hot semi-arid environment of western India. *Indian Journal of Agricultural Sciences* **84**: 80-86.

Singh J. 2013. An unusual occurrence vivipery in papaya (*Carica papaya* L.). *Hort Flora Research Spectrum* **2**: 374-375.

Singhal V K, Salwan A, Kuma P and Kaur J. 2011. Phenology, pollination and breeding system of *Aegle marmelos* (L.) Correa (Rutaceae) from India. *New Forests* **42**: 85-100.

Stoutmeyer V T. 1960. Seed propagation as a nursery technique. *Proc. of Plant Prop agation Society* **10**: 251-55.

Swingle W T. 1928. Metaxenia in the date palm, possibly a hormone action by the embryo or endosperm. *Journal of Heredity* **19**: 257-68.

Ullah M A and Haque M A. 2008. Studies on fruiting, bearing habit and fruit growth of jackfruit germplasm. *Bangladesh Journal of Agri. Res.* **33**: 391-97.

Wallace H M and Lee L S. 1999. Pollen source, fruit set and xenia in mandarins. *Journal of Horticultural Science and Biotechnology* **74**: 82-86.