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# Variability in flowering behaviour and physico-chemical traits of bael (*Aegle marmelos*) cultivars under subtropical conditions

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## ABSTRACT

Nine cultivars of bael (*Aegle marmelos* Correa.) were evaluated under subtropical conditions at Experimental Research Farm of ICAR-Central Institute for Subtropical Horticulture, Rehmankhera, Lucknow, in Randomized Block Design for two consecutive years, i.e. 2016 and 2017. The maximum terminal leaf length (13.50 cm) and breadth (8.40 cm) were recorded in cv. CISH-B-2, lateral leaf length (10.38 cm) in CISH-B-2 and lateral leaf breadth (6.54 cm) in NB-5. The flowering period started from 15$^{th}$ May and continued till 29$^{th}$ June with peak flowering observed during the second and third week of June. Fruit weight ranged 0.746 kg to 1.80 kg, fruit circumference from 37.5 to 50.01 cm and fruit length from 9.10–17.20 cm. Similarly, seeds/fruit varied from 82–156, number of seed sacs per fruit 11–18, seed percentage 0.36–1.08%, shell weight 0.150–0.548 g, shell percentage 14.46–21.54%, shell thickness 1.6–3.4mm. Pulp percentage varied from 57.63–82.39%. Rich variability was recorded in some biochemical traits of the fruits. The study exemplifes that ample variability is available in bael cultivars which may be utilized for improving production and productivity.

**Key words:** Bael, Fruit weight, Pulp percentage, Shell percentage, Yield.

Bael (*Aegle marmelos* Correa.) popularly known as "Bengal quince' belongs to the family Rutaceae. It is an important indigenous fruit of India with a high nutraceutical significance. Though a crop of subtropical origin, bael has much wider adaptability and can perform equally well in tropical, arid and semi-arid regions. In India, it is mainly found wild and semi-wild in dry forests, on hills and plains. It has a reputation for being able to grow in places where other trees generally fail to establish. Bael fruit is rich in protein, fat, minerals (Ca and Fe) and vitamins (riboflavin, carotene and Vitamin C).

Due to high nutritional, medicinal and pesticidal values, bael has been a valued fruit since the pre-historic times (Singh and Mishra 2010). The ripe fruit is sweet, aromatic, nutritious and helps in the regeneration of skin. Fruit pulp shows laxative and febrifuge properties and is good for the heart and brain (Charoensiddhi and Anuprung 2008).

Studies on physico-chemical attributes (Ram and Singh 2003), floral traits and on yield (Singh *et al.* 2014) of some bael varieties have been reported. However, systematic study on characterization of newly developed bael cultivars is lacking particularly under North Indian conditions. Hence, the present investigation was conducted to study the performance of bael cultivars under subtropical conditions, so that unproductive wastelands of the region may be used for bael cultivation leading to better incomes to the farmers, and nutritional security.

## MATERIALS AND METHODS

The experiment was carried out at the experimental farm of ICAR-Central Institute for Subtropical Horticulture, Rehmankhera, Lucknow, Uttar Pradesh, India, during the years 2014 and 2015. The experimental site is located at 26°50'N latitude and 80°23'E longitude with an altitude of 252 m amsl. Experimental site has a humid subtropical climate with cool dry winter from mid-November to February and dry hot summers from late March to June. The rainy season starts from late June to mid-September, however, sometimes rains occur in the month of January. During the year 2014-15 maximum mean monthly temperature was 39.8°C in the month of June and mean monthly minimum temperature of 6.2°C was recorded in the month of December, 2014. The location received mean cumulative rainfall of 732.3 mm during 2014–15. The soil of the experimental site belongs to the major group of Indo-gangetic alluvium with well drained sandy loam texture. Taxonomically, the experimental soil is mixed hyperthermic type ustrocrepts with *p*H 6.84–7.12 and EC of 1: 2.5, soil: water suspension was 0.19 dS/m. Initial soil organic carbon was 0.46%, P 12.7 mg/kg soil and K 78.4 mg/kg soil.

Nine bael cultivars, viz. CISH-B-1, CISH-B-2, NB-5,

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NB-9, NB-16, NB-17, Pant Aparna, Pant Sujata and Pant Shivani planted during the year 2001 and maintained under uniform cultural practices were used as experimental material for comparative characterization. The experiment was laid out in randomized block design with five replications and single tree was treated as a unit per treatment. Observations on vegetative characters, viz. plant height, stem girth and plant spread were recorded during the month of November in both the years of experiment. For recording observations on leaf traits, 20 leaves were collected from $4^{th}$–$5^{th}$ position from the base of 6-months-old shoots from the middle portion of the trees. Twenty shoots spread over four directions on each selected tree were tagged for recording the floral observations like date of flower bud emergence and flowering period in May during both the years. Four fruits were randomly selected from all the directions of the plant for the analysis of quantitative and qualitative characters. Fruit length, fruit circumference, fruit weight, shell weight, shell thickness, total number of seeds, number of seed sacs per fruit and seed weight were recorded by using standard methods and procedures.

Biochemical parameters, viz. total soluble solids were estimated at ambient temperature by digital hand refractometer. Titrable acidity was calculated by titrating the fruit pulp extract with 0.1N NaOH using phenolphthalein indicator (Rangana 1979). Ascorbic acid, total sugar, reducing sugar, tanins and total carotenoid content in fruit sample were estimated by the methods described by Ranganna (2010). The pooled data of both the years were statistically analysed as per method described by Gomez and Gomez (1984) using OPSTAT (http://14.139.232.166/opstat/) and XLSTAT (https://www.xlstat.com/ ) software.

## RESULTS AND DISCUSSION

Terminal leaflet size in terms of length (13.80 cm) was found maximum in *cv*. NB-16 followed by NB-17 (13.71 cm) and was minimum (11.14 cm) in *cv*. NB-9 (Table 1). The terminal leaf breadth was found maximum (8.45 cm) in *cv*. Pant Sujata followed by CISH-B-2 (8.40 cm) and Pant Aparna (8.15 cm) and Pant Shivani (8.11 cm) and was minimum (5.95 cm) in NB-16. The length of lateral leaflet ranged from 7.54 to 10.38 cm among the different cultivars evaluated being maximum in cultivar CISH-B-2 and minimum in cultivar NB-9. Variability in leaf morphology in different varieties might be due to genetic composition of a particular variety. In general, leaves are important for photosynthesis, respiration, transpiration and biophysical reaction of the plant. The shape and size of leaf play an important role in the growth of plants. Leaves having less width with more length are important to control the transpiration in water scarcity condition (Singh 2007). Earlier terminal leaflet was found to be larger than side leaflets (Bhawna and Misra 2011) which results in significant variability in the leaf area among the bael clones (Gupta 1999).

Table 1 Morphometrics of vegetative characters of fruits of different bael cultivars

| Variety | Terminal leaf size | | Lateral leaf size | |
|---|---|---|---|---|
| | Length (cm) | Breadth (cm) | Length (cm) | Breadth (cm) |
| CISHB-1 | 11.50 | 6.10 | 8.17 | 4.50 |
| CISHB-2 | 13.50 | 8.40 | 10.38 | 6.30 |
| NB-5 | 11.84 | 7.40 | 9.13 | 6.54 |
| NB-9 | 11.14 | 6.90 | 7.54 | 4.53 |
| NB-16 | 13.80 | 5.95 | 8.56 | 4.01 |
| NB-17 | 13.71 | 8.01 | 8.13 | 4.53 |
| Pant Aparna | 12.67 | 8.15 | 9.58 | 6.72 |
| Pant Sujata | 11.84 | 8.45 | 8.63 | 6.41 |
| Pant Shivani | 13.69 | 8.11 | 9.15 | 6.11 |
| CD 5% (P<0.05) | 1.40 | 0.87 | 0.95 | 0.59 |

Flowering is believed to be the most important trait and is affected by many factors such as soil fertility, soil water content and other environmental factors. Data regarding flower bud emergence and duration reveal that earliest flower bud emergence took place in NB-5 (120 days) followed by Pant Sujata (128 days), NB-17 and CISH-B-1 (130 days), Pant Aparna (131 days) and late in *cv*. NB-9 (142 days) calculated from Julian day (Fig 1). The flower bud emergence in most of the cultivars continued till the last week of June. The peak period of bud emergence lies between $3^{rd}$ and $4^{th}$ week of May in majority of cultivars, except NB-9 which showed peak bud emergence in $1^{st}$ week of June. The peak period of flowering lies between $2^{nd}$ and $3^{rd}$ week of June while end of flowering takes place between 167 days to 180 days in all the studied cultivars. Variation in floral traits among bael cultivars have also been reported under different climatic conditions (Singh *et al.* 2014, Singh and Misra 2004, Lal 2002).

Significant variability was found in the fruit morphological characters of different cultivars. Maximum fruit weight was recorded in variety NB-17 (1.80 kg) while minimum weight was found in *cv*. NB-5 (0.746 kg). The *cvs* CISH-B-2 (1.69 kg), NB-9 (1.60 kg), Pant Shivani

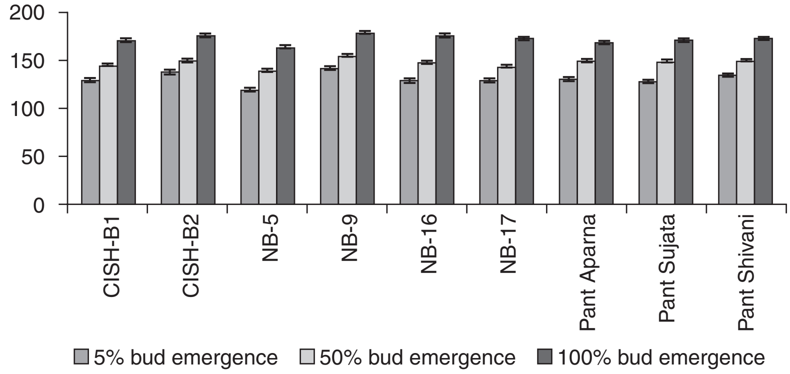


Fig 1 Flowering behaviour of different bael cultivars/selections.

(1.40 kg) and Pant Sujata (1.20 kg) recorded higher fruit weight. Significant variation was also observed in terms of fruit size. Fruit length was found maximum in CISH-B-1 (17.20 cm) followed by CISH-B-2 (14.02 cm) and NB-17 (13.80 cm). On the other hand maximum fruit circumference was observed in CISH-B-2 (50.01 cm) followed by NB-17 (47.40 cm) and NB-9 (44.00 cm) (Table 2).

Variability in number of seeds/fruit, shell weight, shell thickness, seed weight and pulp weight were observed among the different cultivars evaluated. Cultivar CISH-B-2 recorded highest number of seeds/fruit (156.0 seeds/fruit) followed by NB-16 (130.0 seeds/fruit) while lower number of seeds/fruit was recorded in *cv*. NB-5 (82.0). The cultivars having less number of seed (<100/fruit) are CISH-B-1, NB-5, NB-9, Pant Aparna, Pant Sujata. The highest number of seed sac in fruits was observed in *cv*. NB-17 (18), whereas Pant Shivani recorded minimum number of seed sac (11) per fruit. Similarly, maximum shell weight was recorded in cv. CISH-B-2 (0.548 g) followed by NB-9 and Pant Shivani (0.300 g each). Bael variety NB-9 had the thickest shell (3.4 mm) among all the cultivars which was statistically at par with NB-16 and Pant Sujata (3.2 mm) while *cv.* NB-5 recorded the lowest shell thickness (1.6 mm). The seed percentage varied from 0.36 to 1.08 among the different cultivars. Cultivars with low seed content are Pant Shivani (0.50%), NB-9 (0.53%), Pant Sujata (0.67%), NB-16 (0.81%) and CISH-B-1 (0.85%). Similarly, the maximum pulp content was recorded in *cv.* Pant Aparna (82.39%). The cultivars having higher pulp percentage are Pant Sujata (80.72%), Shivani (70.74%), CISH-B-1 (72.50%), NB-17 (72.43%) (Table 2).

The fruit size in terms of fruit length and fruit circumferences and fruit weight was found to vary among the nine bael cultivars. Variability in fruit size among different bael clones was reported earlier also (Singh *et al.* 2014, Pandey *et al.* 2013). Maximum fruit weight was recorded in variety NB-17 while minimum weight was found in *cv*. NB-5. Significant variability was observed in terms of fruit size also. Fruit length was found maximum in CISH-B-1 and minimum was found in NB-5. On the other hand maximum fruit circumference was observed in CISH-B-2. The variability in fruit size, weight and volume was also observed in different bael varieties (Jaiswal 1997, Singh *et al.* 2000, Saroj *et al.* 2008). Maximum shell percentage was found in *cv*. CISH-B-2 (32.64%) followed by *cv*.NB-5 (28.38%).

Data on fruit shape revealed considerable variability in different cultivars with respect to fruit shape. The fruit shape was oval to oblong (CISH-B-1), oblong to round (CISH-B-2), whereas it was round in NB-5, NB-16 and NB-17. Contrary to this variety NB-9 exhibited shape of oblong round with smooth surface. Globose shape was found in Pant Aparna, globule in Pant Sujata and ovoid oblong in Pant Shivani. There was slight variation in fruit colour in different varieties of bael at ripening. Yellowish green colour was observed in CISH-B-1, CISH-B-2, NB-5, NB-17, Pant Aparna, Pant Sujata and Pant Shivani while whitish green colour was visualized in NB-9 and NB-16.

The maximum seed percentage was recorded in *cv*. NB-5 and minimum in *cv*. NB-17. Similarly, the pulp

Table 2 Morphological characters of fruits of different bael cultivars/selections

| Variety | Fruit wt (kg) | Fruit size (cm) | | No. of seeds fruit | No. of seed sac/fruit | Shell wt. (g) | Seed (%) | Pulp (%) | Shell (%) | Shell thickness (mm) | Colour | Shape |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Length | Circumference | | | | | | | | | |
| CISH-B1 | 1.100 | 17.2 | 39.0 | 84 | 15 | 0.230 | 0.85 | 72.50 | 20.38 | 2.8 | Yellowish green | Oval to oblong |
| CISH-B2 | 1.690 | 14.02 | 50.01 | 156 | 15 | 0.548 | 1.07 | 65.64 | 32.46 | 2.1 | Yellowish green | Oblong to round |
| NB-5 | 0.746 | 9.10 | 37.5 | 82 | 13 | 0.210 | 1.08 | 57.63 | 28.38 | 1.6 | Yellowish green | Round |
| NB-9 | 1.600 | 13.6 | 44.0 | 95 | 12 | 0.300 | 0.53 | 68.47 | 18.51 | 3.4 | Whitish green | Oblong round with smooth surface |
| NB-16 | 1.00 | 13.0 | 38.3 | 130 | 16 | 0.239 | 0.81 | 69.14 | 23.78 | 3.2 | Whitish green | Round |
| NB-17 | 1.800 | 13.8 | 47.4 | 100 | 18 | 0.260 | 0.36 | 72.43 | 14.46 | 2.8 | Yellowish green | Round |
| Pant Aparna | 0.900 | 11.10 | 38.6 | 89 | 12 | 0.150 | 0.87 | 82.39 | 16.63 | 2.8 | Yellowish green | Globose shaped |
| Pant Sujata | 1.200 | 12.10 | 41.2 | 88 | 14 | 0.220 | 0.67 | 80.72 | 18.48 | 3.2 | Yellowish green | Globe shape |
| Pant Shivani | 1.400 | 12.0 | 39.0 | 125 | 11 | 0.300 | 0.50 | 70.74 | 21.54 | 3.1 | Yellowish green | Ovoid oblong |
| CD (P=0.05) | 0.092 | 0.47 | 0.523 | 3.00 | 1.60 | 0.052 | 0.018 | 0.064 | 0.116 | 0.38 | | |

percentage ranged from 57.63 to 82.39% among the different cultivars. The maximum pulp content was recorded in *cv.* Pant Aparna (82.39%). Maximum shell percentage was found in *cv*. CISH-B-2, whereas minimum shell percentage was recorded in *cv*. NB-17 (14.46%). The peel content was in the range of 20.54-36.11% and edible portion of fruit varied from 56.12-77.26% in different cultivars (Roy and Singh 1978). Rind content was found in the range 19.0-26.4% and edible portion was recorded in the range of 63.83-77.52% which is in accordance with earlier reports (Jaiswal 1997). Edible portion of the fruit consisted 339.8 to 1201.8 g pulp/fruit which is in conformity with earlier report (Teaotia *et al.* 1963). Considerable variability found in number of seeds in different cultivars is in accordance with earlier reports (Teaotia *et al.* 1963, Singh *et al.* 2000).

It is evident from the results that the fruit attributes vary greatly in all the cultivars. Variability in the various qualitative and quantitative characters of bael fruits of different cultivars might be due to interaction of genetic and environmental factors.

It is apparent from the data that bael cultivars exhibited significant variations in their qualitative traits also. Maximum TSS in the pulp was found in *cv*. NB-17 (36.0°B) closely followed by Pant Shivani (35.0°B), while minimum TSS content was found in *cv*. CISH-B-2 (30.0°B). Maximum acidity was found in Pant Aparna (0.46%) and minimum in CISH-B-2 (0.38%). Ascorbic acid content varied significantly from 6.90-16.90 mg/100g. Pant Shivani (16.90 mg/100g) was found to have maximum ascorbic acid followed by Pant Sujata (15.96 mg/100g) and Pant Aparna (15.29 mg/100g). Total sugar content was maximum in cultivar NB-17 (21.20%), followed by Pant Aparna (20.50%) and NB-5 (20.20%), whereas minimum in CISH-B-2 and NB-16 (18.20%) each. The cultivar NB-17 recorded maximum reducing sugar, i.e. 10.12% followed by Pant Aparna (9.95%) and NB-5 (9.88%). Considerable variability in tannin and carotenoid content was also found. Regarding tannin content, cultivar CISH-B-1 (3.66%) recorded highest value followed by NB-17 (2.95%) and NB-5 and Pant Sujata (2.91%) while lowest value was observed in CISH-B-2 (2.55%). Similarly, total carotenoids content ranged from (0.092-0.099 mg/100g) (Table 3).

More TSS in a fruit is useful in medicinal as well as processing industry. Earlier maximum TSS content in bael was reported under Ranchi condition, i.e. 39.00°B (Jana *et al.* 2014). The variability in acidity among bael germplasm was also reported by Raju *et al.* (2014). The results regarding variability in ascorbic acid among different cultivars are in conformity with the findings of Pandey *et al.* (2006, 2013). Singh *et al.* (2014) studied ascorbic acid content in different bael genotypes and reported maximum ascorbic acid in Goma Yashi followed by NB-5 and NB-7 and minimum in Pant Sujata. Pandey *et al.* (2006) recorded variation in total sugar content from 17.85 to 25.72% in bael cultivars in different locations of UP and Bihar. Variation in reducing sugar content was from 8.38 to 11.38% (Pandey *et al.* 2006). Under different locations of eastern Uttar Pardesh tannin content in different genotypes of bael was found to vary from 2.01 to 4.53% (Pandey *et al.* 2013).

Variability in the qualitative attributes of bael germplasm at different locations might be due to varied agro-climatic conditions, root distribution pattern of individual variety, availability of nutrient to individual plant, management practices of the crop and genetic make-up of the germplasm. Singh *et al.* (2000) and Pandey *et al.* (2008) reported variation in biochemical composition of bael genotypes under different locations. Similarly, variability among different bael varieties in terms of bio-chemical composition among fruits of different bael genotypes from West Bengal, Uttar Pradesh, Bihar, Jharkhand and East Central India was also reported by Singh *et al.* (2014), Pandey *et al.* (2008, 2005), Saroj *et al.* (2008), Nath (2003), Singh *et al.* (2000) and Mazumdar (1975).

Considerable variability was found in the morphological and quality parameters. It is evident from the study that selected cultivars are diverse in nature. Variability is an important pre-requisite for fruit crop improvement. Being medicinally valued fruit crop selected cultivars showed significant variability in nutritional traits as well. Based on the overall performance of the varieties NB-5, CISH-B-1, CISH-B-2, Pant Shivani and NB-9 were found to be superior under subtropical environment of North India, these

Table 3 Biochemical characters fruits of different bael cultivars/selections

| Variety | TSS (°B) | Acidity (%) | Ascorbic acid (mg/100g) | Total carotenoid (mg/100g) | Total sugar (%) | Reducing sugar (%) | Tannin (%) |
|---|---|---|---|---|---|---|---|
| CISH-B1 | 31 | 0.40 | 7.90 | 0.092 | 19.15 | 9.00 | 3.66 |
| CISH-B2 | 30 | 0.38 | 9.25 | 0.092 | 18.20 | 7.66 | 2.55 |
| NB-5 | 32 | 0.40 | 7.75 | 0.099 | 20.20 | 9.88 | 2.91 |
| NB-9 | 34 | 0.41 | 8.11 | 0.099 | 20.11 | 9.11 | 2.89 |
| NB-16 | 31 | 0.39 | 7.40 | 0.093 | 18.20 | 9.02 | 2.90 |
| NB-17 | 36 | 0.39 | 6.90 | 0.095 | 21.20 | 10.12 | 2.95 |
| Pant Aparna | 34 | 0.46 | 15.29 | 0.099 | 20.50 | 9.95 | 2.65 |
| Pant Sujata | 33 | 0.43 | 15.96 | 0.099 | 19.65 | 9.30 | 2.91 |
| Pant Shivani | 35 | 0.41 | 16.90 | 0.093 | 18.20 | 9.10 | 2.90 |
| CD (P=0.05) | 1.2 | 0.01 | 0.23 | 0.07 | 0.51 | 0.48 | 0.39 |

cultivars may be recommended for large scale commercial cultivation.

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