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Evaluation of biochemical attributes of seedling bael (*Aegle marmelos* (L.) Correa.) genotypes under Bastar Plateau conditions of Chhattisgarh

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Abstract
An experiment entitled "Evaluation of biochemical attributes of seedling bael (*Aegle marmelos* (L.) Correa.) genotypes under Bastar Plateau conditions of Chhattisgarh" was conducted during the year 2024-25 at Krantikari Debridhur College of Horticulture and Research Station, Jagdalpur, MGUVV, Durg, Chhattisgarh, to assess the biochemical attributes of 50 seedling bael genotypes. The experiment was laid out in a Randomized Block Design (RBD) with four replications for each genotype. The present investigation revealed significant variability among the bael genotypes for biochemical parameters. Genotype T_{18} recorded the highest TSS (44.30 °Brix) followed by T_{28} (43.61 °Brix). The maximum acidity was observed in T_{27} (0.323%) and was closely followed by T_{43} (0.319%). The highest TSS/Acid ratio was exhibited by T_{28} (274.29) and T_{18} (273.09). With respect to sugar fractions, T_{18} recorded the highest total sugars (16.05%), which was very close to T_{28} (16.04%). Genotype T_{50} (9.18%) showed superiority in reducing sugars followed by T_{16} (8.83%). For non-reducing sugars, T_{18} (9.53%) was found superior, while T_{28} (9.44%) also exhibited higher values. The highest ascorbic acid content was recorded in T_{43} (16.98 mg/100 g) followed by T_{21} (16.35 mg/100 g). These promising genotypes (T_{18}, T_{28}, T_{27}, T_{16}, T_{23}, T_{50}, and T_{43}) exhibited superior biochemical attributes, making them valuable for varietal improvement in bael. Their distinctive combination of high TSS, sugars, balanced acidity, and enriched ascorbic acid content highlights their potential for future breeding programmes, commercial cultivation, and development of value-added products.

Keywords: *Aegle marmelos* (L.) Correa., genotypes, total soluble solids (ºBrix), titratable acidity, total sugar, reducing sugar, non reducing sugars, acidity, ascorbic acid

1. Introduction
Bael (*Aegle marmelos* (L.) Correa) is considered one of the most valued traditional fruit trees of India, recognized for its adaptability and diverse therapeutic properties. However, despite its significance, it has not achieved the same level of commercial utilization as many other fruit crops. Taxonomically, it belongs to the Rutaceae family and is locally referred to by several vernacular names, including bel, belwa, sriphal, stone apple, Bengal quince, bilva, Indian quince, golden apple, holy fruit, and maredo (Singh *et al*., 2019) [19]. This fruit is primarily cultivated in the dry, deciduous forests of central and southern India, as well as across the Indo-Gangetic plains and the Sub-Himalayan region, up to an altitude of 500 meters in North-East India (Neeraj *et al*., 2017) [8]. Bael fruit is a rich source of essential nutrients and has long been valued for its nutritional as well as medicinal properties. The edible portion of 100 g contains 64.2% moisture, 1.8% protein, 0.2% fat, 1.5% minerals, 2.2% fibre, and 30.6% carbohydrates. It also provides important minerals such as iron (0.3%), calcium (0.09%), phosphorus (0.05%), and potassium (0.6%). In terms of vitamins, it is a good source of vitamin A (186 IU), thiamine or vitamin B_1 (0.01%), riboflavin or vitamin B_2 (1.2%), and vitamin C (0.01%) (Parichha, 2004) [10]. Owning to its high nutritive value and the presence of bioactive compounds, bael is also considered important in modern dietary and health practices.
According to 2023 estimates, India had 9.59 thousand hectares under bael cultivation with an annual production of 65.55 thousand tonnes (Department of agriculture and farmers welfare).

Odisha was the leading bael-producing state, occupying 7.30 thousand hectares with a production of 46.36 thousand tonnes. In Chhattisgarh, bael is cultivated over 0.079 thousand hectares, yielding about 0.526 thousand tonnes annually, while Mahasamund district ranks highest within the state, covering 0.048 thousand hectares and contributing 0.361 thousand tonnes (Department of Agriculture, Govt. of C.G.).

Various parts of the plant, including the fruit, trunk, bark, leaves, and roots, are widely used in numerous Ayurvedic remedies (Jauhari *et al*., 1971) [4]. The fruit has a wide range of medicinal applications, with different plant parts being employed in the treatment of ailments such as diarrhea, dysentery, and digestive disorders in both Ayurvedic and Unani medicine. Bael is also recognized as one of the most nutrient-rich fruits. The demand for natural antioxidants and functional foods is increasing in the global market, and bael holds great potential for the development of such products.

Understanding the chemical characteristics of bael genotypes is important for selecting superior varieties that meet consumer preference and ensure economic value. In this context, the present study was undertaken to evaluate the biochemical properties of different bael genotypes cultivated in the Bastar region.

2. Materials and Methods

2.1 Experimental Site

The present experiment was carried out during the year 2024-25 on already existing seedling bael genotypes located in different villages under Jagdalpur block of Bastar district, comprising 50 treatments with 4 replications in a Randomized Block Design (RBD). The biochemical analysis of the collected fruit samples was conducted in the Biochemical Analysis Laboratory of Krantikari Debridhur College of Horticulture and Research Station, Jagdalpur, Bastar, Chhattisgarh, India.

2.2 Methods of experiment

2.2.1 Total Soluble Solids (ºBrix)

The Total Soluble Solids (TSS) content of fruit juice was measured using a handheld refractometer, calibrated with distilled water before each use. Juice was extracted by crushing pulp through muslin cloth, and a drop of clear juice was placed on the prism. Readings were taken against natural light and expressed in °Brix.

2.2.2 Titratable acidity (%)

Titratable acidity was estimated by acid-base titration following the method of Ranganna (1986) [27]. Ten grams of pulp were homogenized with distilled water, made up to 100 ml, and filtered. A 10 ml aliquot of the filtrate was titrated against 0.1 N NaOH using phenolphthalein as an indicator until a faint pink endpoint persisted. The results were expressed as percent citric acid using the formula:

Titratable Acidity (% as citric acid) = (Titre value × Normality of NaOH × Volume made up × Eq. Wt. of acid × 100)/(Aliquot volume × Sample weight × 1000)

2.2.3 Total soluble solid/Acid ratio

The TSS to Acid ratio (Brix-Acid Ratio), an index of taste and flavour balance in fruits, was calculated using the formula:

TSS/Acid Ratio = Total Soluble Solids (°Brix)/Titratable Acidity (%).

2.2.4 Total sugar (%)

Total sugar content was estimated by the Lane and Eynon method as described by Ranganna (1986) [27]. A 50 ml aliquot of the extract was hydrolyzed with concentrated HCl and kept for 24 hours for inversion of sucrose, then neutralized with NaOH using phenolphthalein as an indicator and diluted to 250 ml. The hydrolyzed solution was titrated against Fehling's solution (A and B) using methylene blue as an indicator until the endpoint (brick-red precipitate) was reached. The total sugar content was calculated using the formula:

Total Sugars (%) = (Fehling's factor × Dilution factor × 100)/(Titre value × Volume of sample taken for hydrolysis)

2.2.5 Reducing sugar (%)

Reducing sugar content was determined directly from the aqueous pulp extract using the Lane and Eynon method (Ranganna, 1986) [27]. A 5 g pulp sample was macerated with distilled water, heated, filtered, re-extracted, and the combined filtrates were made up to 250 ml. The extract was titrated against boiling Fehling's solution (A and B) using methylene blue as an indicator until the reddish-brown endpoint appeared. The reducing sugar content was calculated using the formula:

Reducing Sugars (%) = (Fehling's factor × Dilution factor × 100)/(Titre value × Weight of sample)

2.2.6 Non-reducing sugar (%)

Non-reducing sugar content (primarily sucrose) was obtained by subtracting reducing sugars from total sugars, using the formula:

Non-Reducing Sugars (%) = Total Sugars (%)-Reducing Sugars (%)

2.2.7 Ascorbic acid (mg/100 g)

Ascorbic acid (Vitamin C) content was estimated by visual titration using 2,6-dichlorophenolindophenol dye (Ranganna, 1986) [27]. A 10 g pulp sample was homogenized in 3% metaphosphoric acid, diluted to 100 ml, and filtered. A 5 ml aliquot was titrated against the standardized dye solution until a light rose-pink endpoint persisted. The ascorbic acid content was calculated as:

Ascorbic Acid (mg/100 g pulp) = (Titre value × Dye factor × Volume made up × 100)/(Aliquot volume × Sample weight)

3. Results and Discussion

3.1 Total soluble solids (°Brix)

The data on total soluble solids (TSS) of bael genotypes are presented in Table 1. In bael genotypes, TSS showed considerable variation, ranging between 28.05 and 44.30 °Brix. The highest value was recorded in T_{18} (44.30 °Brix), with T_{28} (43.61 °Brix) and T_{15} (43.05 °Brix) also showing higher TSS, whereas the lowest value occurred in T_{27} (28.05 °Brix). Similar variation in TSS among bael genotypes has also been reported by Singh *et al*., (2025) [24].

3.2 Titratable acidity (%)

As shown in Table 1, titratable acidity of bael genotypes exhibited considerable variation, ranging between 0.159% and 0.323%. The maximum acidity was observed in T_{27} (0.323%), followed closely by T_{43} (0.319%) and T_{45} (0.318%), while the minimum was recorded in T_{28} (0.159%). Earlier, Singh *et al*. (2024) [25] also emphasized considerable diversity in acidity content of bael fruits across genotypes.

3.3 Total soluble solid/acid ratio

As presented in Table 1, the TSS: Acid ratio of bael genotypes ranged from 86.86 to 274.29. The maximum ratio was observed in T_{28} (274.29), followed by T_{18} (273.08), while the minimum was recorded in T_{27} (86.86). Variation in TSS: Acid ratio among bael germplasm has also been reported by Kumar *et al*. (2017) [26].

Table 1: Qualitative parameters of bael genotypes for total Soluble Solid (°Brix), titratable acidity (%), TSS to acid ratio

Treatment No.	TSS (°Brix)	Titratable Acidity (%)	TSS to acid ratio
T_1	38.71	0.22	174.23
T_2	40.47	0.20	196.29
T_3	30.63	0.29	103.64
T_4	33.70	0.27	124.43
T_5	39.33	0.21	185.08
T_6	33.81	0.26	126.67
T_7	42.26	0.18	223.38
T_8	35.00	0.25	135.50
T_9	35.06	0.26	137.91
T_{10}	36.03	0.24	146.68
T_{11}	32.57	0.27	117.74
T_{12}	40.60	0.20	198.45
T_{13}	37.85	0.23	162.75
T_{14}	36.25	0.24	145.78
T_{15}	43.04	0.18	235.14
T_{16}	40.46	0.20	196.77
T_{17}	30.38	0.29	102.16
T_{18}	44.30	0.16	273.08
T_{19}	33.07	0.27	118.55
T_{20}	32.80	0.27	117.90
T_{21}	30.80	0.29	104.36
T_{22}	34.69	0.26	131.89
T_{23}	31.85	0.28	110.35
T_{24}	35.13	0.25	137.72
T_{25}	36.40	0.24	150.90
T_{26}	39.97	0.20	194.52
T_{27}	28.04	0.32	86.86
T_{28}	43.61	0.15	274.29
T_{29}	33.50	0.27	123.79
T_{30}	32.27	0.28	114.63
T_{31}	36.51	0.24	151.56
T_{32}	39.48	0.21	182.85
T_{33}	32.79	0.27	117.90
T_{34}	36.81	0.23	153.76
T_{35}	35.37	0.25	136.71
T_{36}	34.41	0.26	130.01
T_{37}	38.94	0.21	179.18
T_{38}	40.49	0.20	194.83
T_{39}	38.45	0.22	169.46
T_{40}	32.10	0.28	113.10
T_{41}	39.67	0.21	186.79
T_{42}	38.88	0.21	179.02
T_{43}	28.40	0.31	89.08
T_{44}	33.05	0.27	119.72
T_{45}	28.46	0.31	89.63
T_{46}	36.36	0.24	147.54
T_{47}	37.00	0.23	154.66
T_{48}	38.60	0.22	171.09
T_{49}	37.02	0.23	155.61
T_{50}	40.64	0.20	199.82
S.Em±	0.16	0.003	2.59
C.D. at 5%	0.45	0.01	7.24
C.V.	0.95	2.90	3.37

Table 2: Qualitative parameters of bael genotypes for total sugar (%), reducing sugar (%) and non-reducing sugar (%), and Ascorbic acid (mg/100 g pulp)

Treatment No.	Total Sugar (%)	Reducing Sugar (%	Non-Reducing Sugar (%)	Ascorbic acid (mg/100 g pulp)
T_1	13.56	6.35	7.21	12.01
T_2	14.47	5.35	9.12	10.62
T_3	9.43	3.98	5.45	16.02
T_4	10.75	4.04	6.71	14.72
T_5	14.26	6.00	8.25	11.23
T_6	11.16	6.25	4.91	14.66
T_7	15.44	8.70	6.73	9.23
T_8	11.69	5.13	6.56	14.23
T_9	11.83	5.97	5.85	13.90
T_{10}	12.42	5.09	7.33	13.56
T_{11}	10.56	4.71	5.84	15.43
T_{12}	14.53	5.40	9.12	9.81
T_{13}	13.08	6.85	6.23	12.62
T_{14}	12.02	5.84	6.18	13.69
T_{15}	15.75	7.46	8.29	8.83
T_{16}	14.67	8.83	5.84	10.70
T_{17}	9.48	3.56	5.92	16.05
T_{18}	16.04	6.52	9.52	8.39
T_{19}	10.53	3.75	6.77	14.94
T_{20}	10.38	5.37	5.00	15.29
T_{21}	9.46	4.42	5.03	16.34
T_{22}	11.40	4.59	6.81	14.33
T_{23}	9.97	4.71	5.25	15.89
T_{24}	11.70	5.62	6.08	13.92
T_{25}	12.55	6.66	5.88	13.40
T_{26}	14.75	6.98	7.76	10.86
T_{27}	8.08	3.15	4.93	16.08
T_{28}	16.03	6.59	9.44	8.27
T_{29}	11.01	4.13	6.88	14.86
T_{30}	10.27	4.07	6.19	15.61
T_{31}	12.55	7.65	4.89	13.65
T_{32}	13.97	8.01	5.95	11.18
T_{33}	10.64	5.62	5.02	15.40
T_{34}	12.74	5.66	7.08	13.37
T_{35}	11.48	5.03	6.45	13.72
T_{36}	11.23	4.31	6.92	14.39
T_{37}	14.05	5.25	8.79	11.27
T_{38}	14.44	6.22	8.21	10.21
T_{39}	13.55	4.90	8.65	12.79
T_{40}	10.17	4.63	5.54	15.66
T_{41}	13.91	6.24	7.67	10.95
T_{42}	14.1	8.22	5.87	11.49
T_{43}	8.19	4.47	3.72	16.98
T_{44}	10.63	5.87	4.75	14.96
T_{45}	8.25	4.94	3.30	16.16
T_{46}	12.22	4.37	7.85	13.21
T_{47}	12.64	6.28	6.36	13.31
T_{48}	13.46	4.95	8.51	12.17
T_{49}	12.82	5.89	6.93	13.21
T_{50}	14.59	9.17	5.42	9.39
S.Em±	0.09	0.13	014	0.01
C.D. at 5%	0.26	0.37	0.39	0.04
C.V	1.54	4.61	4.29	0.22

3.4 Total sugar (%)

As presented in Table 2, total sugar content of bael genotypes ranged from 8.08% to 16.04%, with the highest in T_{18} (16.04%) followed by T_{28} (16.03%), and the lowest recorded in T_{27} (8.08%).Variation in total sugar levels among bael genotypes has also been documented by Kumar *et al*. in studies of bael germplasm under semi-arid conditions.

3.5 Reducing sugar (%)

As presented in Table 2, reducing sugar content of bael genotypes varied from 3.15% to 9.17%. The maximum was recorded in T_{50} (9.17%), followed by T_{16} (8.83%), whereas the minimum was observed in T_{27} (3.15%).

3.6 Non Reducing sugar (%)

As presented in Table 2, non-reducing sugar content of bael genotypes ranged from 3.30% to 9.52%. The maximum was recorded in T_{18} (9.52%), followed by T_{28} (9.44%), while the minimum was noted in T_{45} (3.30%).

3.7 Ascorbic acid mg/100 g)

As presented in Table 2, ascorbic acid content of bael genotypes ranged from 8.27 to 16.98 mg/100 g. The highest value was recorded in T_{43} (16.98 mg/100 g), followed by T_{21} (16.34 mg/100 g), while the lowest was observed in T_{28} (8.27 mg/100 g).

4. Conclusion

The biochemical characterization of bael genotypes exhibited marked variation in quality traits such as TSS, acidity, TSS: Acid ratio, sugars, and ascorbic acid content. Genotypes like T_{18} (high TSS, total sugars, and non-reducing sugars), T_{27} (acidity), T_{28} (TSS: Acid ratio), T_{50} and T_{16} (reducing sugars), along with T_{43} and T_{21} (ascorbic acid), emerged as superior performers across different parameters. These promising genotypes represent valuable genetic resources that can be effectively utilized in bael breeding programmes, varietal improvement, and the development of nutritionally rich, value-added products.

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