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Flowering, Fruiting and Physio-chemical Characteristics of Bael (*Aegle marmelos* Correa.) Grown in Northern Districts of West Bengal

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Authors' contributions

This work was carried out in collaboration between all authors. Author AM designed the study, performed the analysis, wrote the protocol and wrote the first draft of the manuscript. Authors AKS and NJ managed the statistical analyses of the study. Author SM managed the literature searches and performed the analysis. All authors read and approved the final manuscript.

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ABSTRACT

A study was conducted during the fruiting season of bael, an important minor fruit of tropics and subtropics on medicinal and religious aspects. This was done to determine the flowering, fruiting and physio-chemical properties of the fruits and to evaluate the best accession collected from different locations. The fruits were harvested from distinct locations on North Bengal and were brought to the lab where they were analysed for their bio-chemical properties. The result showed that all the different accessions have different and distinct characters. By going through all the results, clearly it can be concluded that the bael trees growing wildly in North Bengal or in homestead shows wide variations and diversities. Abundance of flowering and fruiting was profuse in ACC-1, ACC-6, ACC-15, ACC-17, and ACC-25. Earliest fruiting was observed in ACC-11 (17th March) and ACC-20 (17th March). Fewer seeds were observed in ACC-3 (14.33), ACC-9 (13.67), ACC-14 (18.33) and ACC-15 (15.67) which is considered desirable for fresh consumption. Thinnest

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rind was observed in ACC-11 (2.14 mm) followed by ACC-25. Maximum Total Soluble Solids (° Brix) was observed in ACC-25 (16.33 ° Brix). Titratable acidity was recorded maximum in ACC-3 (0.67%) followed by ACC-11 (0.62%). Total sugar was recoded maximum in ACC-11 (11.14%) followed by ACC-25 (10.85%). Maximum reducing sugar was observed in ACC-11 (4.47%) followed by ACC-8 (4.33%), ACC-17 (4.23%) and ACC-25 (4.32%) also showed a high value of reducing sugar content as compared to other accessions. Hence, it could be concluded that ACC-11 (Alipurdwar) is the most superior accessions followed by ACC-25 (Hilli).

Keywords: Bael; accessions; bio-chemical; characterization; Physio-chemical; total soluble solids.

1. INTRODUCTION

Bael (*Aegle marmelos* Correa) belongs to the family Rutaceae and is an important indigenous fruit of India. Bael is purely deciduous and is called with names like Bael, Beli, Belgiri, Vilwa, Bengal quince, Golden apple, Bel Kham Bel and Bilivaphal [1,2]. Bael fruit is a sub-tropical, deciduous tree and fruit is globuse with grey or yellowish hard woody shell. Inside the fruit, soft yellow or orange colored mucilaginous pulp with numerous seeds are present. Bael is abundantly found all over India and a huge diversity exists in bael in the northern districts of Bengal. Bael is found all over India, from sub Himalayan forests, Bengal, Central and in Burma [3]. The tree is also found as a wild tree, in lower ranges of Himalyas up to an elevation of 500 meters. Bael is also found growing along foothills of Himalayas, Uttranchal, Jharkhand, Madhya Pradesh and the Deccan Plateau and along the east coast [4].

There exists enormous variability in the vegetative and reproductive phenology of bael. This can be due to the fact that most of the trees which are found grown wildly or in homestead are grown from sexual seeds. Bael tree have the capability to be grown in dry forests, in hills, in semi-arid regions and even in plains. It can tolerate salinity to some extent and can be grown successfully once the orchard is established under semi-arid or rainfed conditions. Bael tree grows throughout the dry hilly areas, reaches upto 1,300 m tall high in the Western Himalayas, Burma, Pakistan, Bangladesh, Sri Lanka, Northern Malaysia, Java, and Philippine Islands. Bael fruits were introduced in Europe in 1959 [5]. It is called Sivadruma by the Hindus and considered a sacred herb. It is widely found in Indian Siva temples since the herb is considered sacred to Shiva, the lord of health. The leaves of the plant are being offered to Gods as part of prayers. They are also highly valued in Ayurvedic medicines. Bael is in high demand for pharmaceutical purposes [6]. All the parts of the tree, whether it is stem, bark, root, leaf, flower, seed oil, or fruits of any stage of maturity and ripening, are used in various ayurvedic medicines The bael tree contains furocoumarins, including xanthotoxol and the methyl ester of alloimperatorin, as well as flavonoids, rutin and marmesin. Higher concentration of marmelosin is found in ripe fruit pulp as compared to other parts of *Aegle marmelos* tree [7]. All parts of *Aegle marmelos* are medicinally useful like, leaves, fruit pulp, and flower, stem bark, root bark. The fruits and roots of *A. marmelos* Corr. possess antiamoebic and hypoglycemic activity [8]. The alkaloid 'aegeline' present in the leaf is an effective anti-asthmatic agent [8]. It is also good for diabetic patient due to having more mucilage and medicinal contents like caumarin and marmelosin. Its medicinal properties have been described in the ancient medical treatise in Sanskrit in *Charaka-Samhita* [9]. It is very popular in tropical and arid parts of India.

The tree is slow growing and may reach a height of 40-50 feet. Tree has a short trunk and the bark is thick, soft and flaking. Flowers are greenish white, sweetly scented, fruits are yellowish green. The inflorescence contains a bunch of fragrant flowers that vary from 4 to 7 in number [10]. Fragrant, tiny, whitish flowers are borne on the twigs. Flowers in clusters of 4 to 7 along the young branchlets, have 4 recurved, fleshy petals, green outside, yellowish inside, and 50 or more greenish-yellow stamens are. The fruits are also a good source of vitamin C and protein [11]. The flavor of bael is "sweet, aromatic and pleasant, although tangy and slightly astringent in some varieties [12]. Fruit juice is used as a very good coolant and consequently. Bael fruits are hardy and get matured after 10-11 months growing on the tree [13]. Based on the fruits size and shape, the fruits were grouped under five categories (oval, flat, spherical, oblong and pear shaped) and in each group three subgroups (small, medium, big) were separated [14]. Hence, an

attempt had been made to assess the physical and bio-chemical properties of bael so as to do the characterization of best accession out of the entire lot.

2. MATERIALS AND METHODS

2.1 Location and Site of Experiment

The fruits were harvested and collected from different distinct locations of North Bengal during fruiting season of 2016. The fruits collected from a location were of same tree. It was ensured that the trees was vigorous, healthy and in peak reproductive phase (12-20 years). Clean fruits free from biotic and abiotic stress were collected. It was ensured that the fruit samples collected were in perfect maturity, neither unripe nor over ripened. The fruits were at first cleaned in water and then shade dried. The fruit samples were analysed for their physical and chemical properties. The entire experiment was conducted at the post graduate laboratory, Department of Pomology and Postharvest technology, Faculty of Horticulture, Uttar Banga Krishi Viswavidyalaya. The individual plants from distinct locations were considered as different accessions viz. ACC-1, ACC-2, ACC-3, ACC-4 to ACC-25 respectively. Hence, the 25 locations like Coochbehar, Mekhliganj, Pundibari, Dinhata, Sahebganj, Natabari, Baxirhath, Tufanganj, Sitaldaho, Dewanhath, Alipurdwar, Birpara, Falakata, Dhupguri, Mathabhanga, Jalpaiguri, Belacopa, Jaigaon, Raiganj, Balurghat, Gangarampur, Tapan, Kaliaganj, Islampur and Hilli were respectively named as ACC-1, ACC-2, ACC-3, ACC-4 to ACC-25 respectively.

2.2 Design Used in this Experiment

The design of the experiment was Randomized Block Design (RBD) where the 25 different accessions are the 25 treatments and 3 replications.

2.3 Parameters Studied

2.3.1 Physical parameters

The physical analysis of fruit like length and breadth was done using a standard 30 cm scale. The average weight of the fruit was determined digitally by electronic weighing balance. Thorn abundance, onset of flowering, flowering time, fruiting time, abundance of flowering, abundance of fruiting, fruit shape, fruit colour and pulp colour were determined visually by thorough observations and tagging.

2.3.2 Chemical parameters

The Total Soluble Solids (TSS in °B) was estimated by using the hand refractometer. Chemical assessment of the fruits like the titratable acidity (TA), total sugar (TS) and reducing sugar content were determined following the methods suggested by Association of Analytical chemists [15].

3. RESULTS AND DISCUSSION

Table 1 shows the flowering and fruiting characteristics of bael fruit accessions collected from different locations of North Bengal. The vegetative profuseness of the particular tree tagged in a particular location showed variations. ACC-1, ACC-4, ACC-5, ACC-6, ACC-7, ACC-12, ACC-14, ACC-15, ACC-17, ACC-19, ACC-21, ACC-22, ACC-23 and ACC-24 were plants that were highly vegetative vigorous during flowering and fruiting. ACC-2, ACC-3, ACC-9, ACC-18 and ACC-20 were plants which were non-vigorous. ACC-8, ACC-11, ACC-13, ACC-16 and ACC-2 plants were vegetative semi-vigorous during flowering and fruiting. Thorn abundance was high in ACC-1, ACC-2, ACC-4, ACC-, ACC-6, ACC-7, ACC-8, ACC-9, ACC-12, ACC-14, ACC-15, ACC-16, ACC-17, ACC-18, ACC-19, ACC-20, ACC-21, ACC-22, ACC-23 and ACC-24. Fewer thorns were found in trees from ACC-3, ACC-10, ACC-11, ACC-13 and ACC-25. Abundance of flowering was profuse in the trees from ACC-1, ACC-2, ACC-4, ACC-5, ACC-6, ACC-7, ACC-8, ACC-9, ACC-12, ACC-14, ACC-15, ACC-16, ACC-17, ACC-18, ACC-19, ACC-20, ACC-21, ACC-22, ACC-23 and ACC-24. Abundance of fruiting was profuse the plants from ACC-1, ACC-6, ACC-13, ACC-15, ACC-17, ACC-19 and ACC-25. Moderate abundance of fruiting was observed in ACC-2, ACC-4, ACC-, ACC-7, ACC-8, ACC-10, ACC-14, ACC-16, ACC-17, ACC-19 and ACC-25. Sparse abundance of fruiting was observed in ACC-3, ACC-9, ACC-11, ACC-12, ACC-18, ACC-23 and ACC-24. The fruit shape showed enormous variation among different accessions. Oval shaped fruits were found in plants from ACC-1, ACC-12, ACC-13, ACC-16, ACC-19 and ACC-22. Round shaped fruits were found in ACC-2, ACC-4, ACC-7, ACC-10, ACC-11, ACC-14, ACC-17, ACC-20 and ACC-21. Oblong shaped fruits were observed in trees of ACC-3, ACC-6 and ACC-8. Slightly pear shaped fruits were found in ACC-, ACC-15 and ACC-25.

Table 1. Flowering and fruiting characteristics

Accessions	Vegetative profuseness	Thorn abundance	Flowering time	Abundance of flowering	Fruiting time	Abundance of fruiting	Fruit shape
ACC-1	Vigorous	High	11th May	Profuse	7th April	Profuse	Oval
ACC-2	Non-vigorous	High	28th April	Profuse	29th March	moderate	Round
ACC-3	Non- vigorous	Low	7th May	Sparse	10th April	Sparse	Oblong
ACC-4	Vigorous	High	4th May	Profuse	1st April	moderate	Round
ACC-5	Vigorous	High	17th April	moderate	21st March	moderate	Slightly pear shaped
ACC-6	Vigorous	High	16th May	Profuse	14th April	Profuse	Oblong
ACC-7	Vigorous	High	11th May	Profuse	9th April	moderate	Round
ACC-8	Semi-vigorous	High	27th April	Profuse	28th March	moderate	Oblong
ACC-9	Non-vigorous	High	26th April	Sparse	24th March	Sparse	Oblong
ACC-10	Vigorous	Low	1st May	Profuse	2nd April	moderate	Round
ACC-11	Semi- vigorous	Low	20th April	Profuse	17th March	Sparse	Round
ACC-12	Vigorous	High	9th May	moderate	4th April	Sparse	Oval
ACC-13	Semi- vigorous	Low	11th May	Profuse	7th April	Profuse	Oval
ACC-14	Vigorous	High	29th April	Profuse	30th March	Moderate	Round
ACC-15	Vigorous	High	7th May	Profuse	8th April	Profuse	Slightly pear shaped
ACC-16	Semi- vigorous	High	11th May	Moderate	12th April	Moderate	Oval
ACC-17	Vigorous	High	17th May	Profuse	14th April	Profuse	Round
ACC-18	Non-vigorous	High	2nd May	Sparse	4th April	Sparse	Globose
ACC-19	Vigorous	High	14th May	Profuse	16th April	Profuse	Oval
ACC-20	Non- vigorous	High	25th April	Profuse	17th March	Moderate	Round
ACC-21	Vigorous	High	11th May	Profuse	1st April	Moderate	Round
ACC-22	Vigorous	High	5th May	Profuse	5th April	Moderate	Oval
ACC-23	Vigorous	High	14th May	Moderate	10th April	Sparse	Round
ACC-24	Vigorous	High	28th April	Profuse	31st March	Sparse	Round
ACC-25	Semi- vigorous	Low	21st April	Profuse	23rd March	Profuse	Slightly pear shaped

Table 2. Physical characteristics of bael fruit accessions collected from different locations of North Bengal

Accessions	Fruit Weight (g)	Pulp Weight (g)	Rind Weight (g)	Seed Weight (g)	No of seeds	Fruit colour (at edible conditions)	Number of sections	Rind thickness (mm)	Pulp colour
ACC-1	345.39	265.33	74.72	5.33	36.33	Dull green	10	3.18	Yellow
ACC-2	250.75	184.00	61.08	5.67	32	Dull yellow	14	2.18	Orange-yellow
ACC-3	270.37	202.75	62.29	5.33	14.33	Dull yellow	12	3.25	Yellow
ACC-4	293.51	245.00	42.85	5.67	24.67	Dull yellow	12	3.22	orange
ACC-5	280.04	213.00	61.71	5.33	39	Dull yellow	10	3.04	Yellow
ACC-6	273.33	200.56	67.11	5.67	24.67	Dull green	16	3.02	Yellow
ACC-7	334.00	257.66	71.01	5.33	33.67	Dull green	16	3.23	Yellow
ACC-8	263.67	191.71	66.29	5.67	23.33	Dull yellow	10	3.30	Orange-yellow
ACC-9	314.91	237.44	72.14	5.33	13.67	Dull yellow	12	3.16	yellow
ACC-10	296.67	235.41	55.59	5.67	34.33	Dull green	12	3.28	Yellow
ACC-11	264.00	187.71	70.96	5.33	22.67	Dull yellow	14	2.14	yellow
ACC-12	328.00	249.32	73.34	5.33	23.33	Dull green	10	2.22	Orange-yellow
ACC-13	290.33	215.79	68.88	5.67	35	Dull yellow	18	3.26	Orange-yellow
ACC-14	264.33	186.62	72.04	5.67	18.33	Dull yellow	20	2.95	Orange-yellow
ACC-15	328.33	249.71	72.96	5.67	15.67	Dull yellow	10	3.13	Yellow
ACC-16	340.81	272.67	62.47	5.67	31.67	Dull yellow	14	2.92	Yellow
ACC-17	268.00	235.60	27.40	5.00	26.33	Dull green	8	3.25	Orange
ACC-18	283.48	206.27	72.21	5.00	36	Dull yellow	16	3.08	Yellow
ACC-19	339.50	268.97	64.87	5.67	23	Dull yellow	12	2.92	yellow
ACC-20	267.00	192.70	68.63	5.67	35.67	Dull yellow	14	3.16	Yellow
ACC-21	317.02	240.36	71.32	5.33	26	Dull yellow	14	3.15	Yellow
ACC-22	288.67	216.93	66.74	5.00	33.67	Dull green	16	3.15	Yellow
ACC-23	354.00	279.27	68.73	6.00	28	Dull yellow	12	2.98	Orange-yellow
ACC-24	300.67	234.85	60.48	5.33	25.33	Dull yellow	10	2.65	Yellow
ACC-25	335.33	259.16	70.51	5.67	33	Dull yellow	10	2.21	Orange-yellow
S.Em.(±)	11.54	11.47	8.42	0.493	2.15	N/A	N/A	0.08	N/A
C.D. at 5%	32.92	32.70	NS	NS	6.14	N/A	N/A	0.24	N/A
C.V.	6.67	8.68	22.41	15.57	13.51	N/A	N/A	4.99	N/A

Table 3. Bio-chemical properties of different bael fruit accessions from North Bengal

Accessions	TSS (in °B)	Titratable acidity (%)	Total sugar (%)	Reducing sugar (%)
ACC-1	14.83	0.47	8.01	3.25
ACC-2	14.83	0.50	8.64	3.63
ACC-3	13.7	0.67	8.71	3.87
ACC-4	15.53	0.48	8.64	3.72
ACC-5	15.6	0.55	8.24	3.48
ACC-6	14.03	0.61	8.01	3.18
ACC-7	14.07	0.48	9.30	4.18
ACC-8	15.8	0.57	10.49	4.33
ACC-9	15.47	0.51	8.27	3.50
ACC-10	14.67	0.44	8.75	3.62
ACC-11	15.27	0.62	11.14	4.47
ACC-12	15.47	0.49	8.82	3.88
ACC-13	16.23	0.51	10.16	4.14
ACC-14	15.27	0.50	7.33	2.86
ACC-15	15.4	0.54	8.84	3.96
ACC-16	15.6	0.57	8.42	3.55
ACC-17	14.83	0.49	9.68	4.23
ACC-18	15.37	0.55	8.49	3.25
ACC-19	15.03	0.47	8.14	3.16
ACC-20	14.83	0.50	8.28	3.13
ACC-21	15	0.54	8.41	3.21
ACC-22	15.83	0.49	8.48	3.36
ACC-23	14.4	0.52	8.31	3.31
ACC-24	14.5	0.56	8.49	3.44
ACC-25	16.33	0.57	10.85	4.32
S.Em.(±)	0.375	0.023	0.331	0.064
C.D. at 5%	1.069	0.066	0.943	0.183
C.V.	4.295	7.522	6.478	3.053

Earliest flowering was observed in ACC-5 (17th April), ACC-11 (20th April) and ACC-25 (21st April). Delayed flowering was observed in ACC-17 (17th May), ACC-6 (16th May), ACC-23 (14th May), ACC-19 (14th May), ACC-1 (11th May) and ACC-7 (11th May). Earliest fruiting was observed in ACC-11 (17th March) and ACC-20 (17th March). Early fruiting was also observed in ACC-5 (21st March) and ACC-25 (23rd March). Late fruiting is observed in ACC-19 (16th April), ACC-6 (14th April), ACC-17 (14th April) and ACC-16 (12th April).

As shown in Table 2, Fruit weight (in g) showed high variations. Highest fruit weight was observed in ACC-23 (354g). However ACC-1 (345.39 g) was also at par with ACC-23 at 5% level of significance. ACC- 16 and ACC-25 also showed higher value of fruit weight of 340.81g and 335.33g respectively. Similarly, ACC-23 (279.27 g) showed highest pulp weight followed by ACC-16 (272.67g), ACC-1 (265.33g) and ACC-25 (259.16 g). However ACC-16 (272.67 g) was also at par with ACC-23 at 5% level of significance. The rind weight (in g) and seed weight (in g) did not show much variation with changing locations and was non-significant at 5% level of significance. Maximum number of seeds (39) was observed in ACC-5. Fewer seeds were observed in ACC-3 (14.33), ACC-9 (13.67), ACC-14 (18.33) and ACC-15 (15.67) which is considered desirable for fresh consumption. Fruit colour (at edible conditions) was dull green in ACC-1, ACC-6, ACC-7, ACC-10, ACC-12, ACC-17 and ACC-22. Fruits from the rest of the accessions were dull yellow in colour at edible maturity. Number of sections inside the fruits also showed huge variations. As observed the number of sections varied from 8 to 18. Rind thickness (in mm) also showed variations. Thinner rind fruits are preferred for fresh consumptions but thicker rind ensures minimum post harvest injuries. Comparatively, thickest rind was observed in ACC-8 (3.30 mm). ACC-3 (3.25 mm), ACC-7 (3.23 mm), ACC-10 (3.28 mm), ACC-13 (3.26) and ACC-17 (3.25) is at par with ACC-8 at 5% level of significance. Thinnest rind was observed in ACC-11 (2.14 mm), followed by

ACC-2 (2.18 mm), ACC-25 (2.21 mm) and ACC-12 (2.22 mm) Pulp colour also showed high variation right from yellow in ACC-1, ACC-3, ACC-5, ACC-6, ACC-7, ACC-9, ACC-10, ACC-11, ACC-15, ACC-16, ACC-18, ACC-19, ACC-20, ACC-21, ACC-22 to orange in ACC-4 and ACC-17 and orange-yellow in ACC-2, ACC-8, ACC-12, ACC-13, ACC-14, ACC-23 and ACC-25.

Table 3 shows the bio-chemical properties of the fruit collected from different locations. Maximum TSS (in °B) was observed in ACC-25 (16.33 °B) and minimum in ACC-3 (13.7 °B). However ACC-25 is at par with ACC-13 (16.23°B). Titratable acidity was recorded maximum in ACC-3 (0.67%) and minimum in ACC-1 and ACC-19 (0.47%). Similarly, ACC-6 (0.61%), ACC-11 (0.62%), ACC-16 (0.57%) and ACC-25 (0.57%) also showed a higher value of titratable acidity. Total sugar was recoded maximum in ACC-11 (11.14%) and minimum in ACC-14 (7.33%). However ACC-25 (10.85%) is found at par with ACC-11 at 5% level of significance. Maximum reducing sugar was observed in ACC-11 (4.47%) and minimum in ACC-14 (2.86%). However ACC-8 (4.33%), ACC-17 (4.23%) and ACC-25 (4.32%) also showed a high value of reducing sugar content as compared to other accessions.

4. CONCLUSION

By going through all the results, clearly it can be concluded that the bael trees growing wildly in North Bengal or in homestead shows wide variations and diversities. Abundance of flowering was profuse in the trees from ACC-1, ACC-2, ACC-4, ACC-5, ACC-6, ACC-7, ACC-8, ACC-9, ACC-12, ACC-14, ACC-15, ACC-16, ACC-17, ACC-18, ACC-19, ACC-20, ACC-21, ACC-22, ACC-23 and ACC-24. Abundance of fruiting was profuse the plants from ACC-1, ACC-6, ACC-13, ACC-15, ACC-17, ACC-19 and ACC-25. Earliest flowering was observed in ACC-5 (17th April), ACC-11 (20th April) and ACC-25 (21st April). Earliest fruiting was observed in ACC-11 (17th March) and ACC-20 (17th March). Fewer seeds were observed in ACC-3 (14.33), ACC-9 (13.67), ACC-14 (18.33) and ACC-15 (15.67) which is considered desirable for fresh consumption. Thinnest rind was observed in ACC-11 (2.14 mm) followed by ACC-25. Maximum TSS (° Brix) was observed in ACC-25 (16.33 ° Brix). Titratable acidity was recorded maximum in ACC-3 (0.67%) followed by ACC-11 (0.62%). Total sugar was recoded maximum in ACC-11 (11.14%) followed by ACC-25 (10.85%). Maximum reducing sugar was observed in ACC-11 (4.47%) followed by ACC-8 (4.33%), ACC-17 (4.23%) and ACC-25 (4.32%) also showed a high value of reducing sugar content as compared to other accessions. Hence, it could be concluded that ACC-11 (location: Alipurdwar, District: Coochbehar) is the most superior accessions followed by ACC-25 (location: Hilli, District: Dakshin Dinajpur).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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