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Performance of SKNB-15 and SKNB-2 germplasm of bael (*Aegle marmelos*) under semi-arid conditions

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Abstract
The investigation on Morpho-physiological, Growth and yield performance of SKN B-15 and SKN B-2 germplasm of bael were carried out during 2021-24 with thirteen other germplasm of bael. These two germplasms (SKN B-15 and SKN B-2) exhibited significant variability in fruit morphology, physiology, yield, frost tolerance and physico-chemical characteristics. The number of fruits per tree ranged from 67 to 150 with fruit yield per tree varying between 27.29 kg and 181.2kg. Fruit weight ranged from 0.41kg to 2.93kg across the germplasm. The important fruit traits, such as fruit length, ranged from 9.21cm to 18.63cm, shell weight per fruit varied from 119.37 g to 391.71g, shell thickness ranged from 0.18cm to 0.34cm, and seed weight per fruit from 0.15 g to 0.32g. The total soluble solids (TSS) ranged from 30.45 to 40.76°Brix among the germplasm analyzed. The frost tolerant capacity was recorded -4°C in SKN B-15 and -2°C in SKN B-2 and chlorophyll content were recorded 1.63mg/g in SKN B-15 and 1.27mg/g in SKN B-2. Based on the overall assessment, the genotypes SKN-15 and SKN-2 were identified as the most promising germplasms.

Keywords: Bael, frost, semi-arid condition, physico-chemical traits and fruit yield

Introduction

Bael (*Aegle marmelos* (L) Correa) is one of the important underutilized, indigenous fruit crops of India, known for its high medicinal and nutritional values. It was found wild in the Sub-Himalayan tract and dry deciduous forests of Central and Southern India. Therefore, a large number of landraces are available in different diversity regions. Each tree is genetically diverse from others as most of them are of seedling origin. Individual tree varies greatly in their morphology; variation may be due to genetically or environmental or both. This heterozygous nature gives scope for further selection and the establishment of desirable trees. Information on magnitude of variation and association of characters is useful as a basis for the selection of desirable types. Hence, identification of elite trees for the region is necessary for promoting its production, productivity and quality of the fruits under the Southern Transitional Zone of Karnataka, India.

The importance of bael fruits lies in its curative, pesticidal and nutritive properties. Ripe fruits are laxative and unripe fruits are prescribed for treatment of diarrhea and dysentery and have a great demand in Ayurvedic system of medicine. Every part of the plant such as fruit, seed, bark, leaf and root are important ingredients of several traditional formulations. Apart from medicinal value, it acts as a sink for chemical pollutants as it absorbs poisonous gases from atmosphere and makes them neutral. The fruit has been known in India since the pre historic era. Bael fruit grows throughout the Indian Peninsula as well as in Sri Lanka, Nepal, Pakistan, Bangladesh, Burma, Thailand and most Southeast Asian countries. Bael is a valuable tree species and its fruits are recognized for their medicinal and nutritive properties. It is traditionally used in curing several diseases and as ingredients of nutritive foods. The livelihoods of some ethnic groups depend on bael fruit collection, processing and marketing (Roy and Singh, 1979) [4]. Keeping in view the above facts investigation was conducted to characterize the bael trees for morphological, yield and yield attributing traits. Therefore, these observations on 15 germplasm of bael taken to identify superior genotypes for various useful traits.

Material and Methods

The investigation on Morpho-physiological, Growth, frost tolerance and yield performance of SKN B-15 and SKN B-2 germplasm of bael were conducted during 2021-24 with thirteen other germplasm of bael of one ICAR-CIAH, Bikaner experiment (AH 1.1.4: Germplasm Repository of Bael) conducting at Asalpur farm under AICRP on AZF Scheme. The date of planting of deshi bael plants was July, 2011. The date of budding by elite germplasm were August to September, 2014. These elite germplasms were collected from a survey of bael germplasms made in the districts of Ajmer, Churu, Jaipur and Jhunjhunu in Rajasthan in 2011. The experiment was conducted in Randomized Block Design with fifteen germplasm and replicated four times, considering one plant as a unit. The names SKN B-2 and SKN B-15 were given to SKN-2 and SKN-15 due to their better morph-physiological, growth and yield performance as compared to other genotypes. The SKN-15 and SKN-2 were collected from Asalpur farm itself, Department of Horticulture, S.K.N. College of Agriculture, Jober.

The goal of investigation was to find only disease free, pest-free, regularly bearing, dwarf trees with thin shells that contained less seed, fiber, and mucilage, had a pleasant scent, and produced uniformly shaped and sized fruits. A total of 15 genotypes having good fruit and tree characters were identified. For each genotype, five fruits were randomly selected from every orientation in order to record the morphological and qualitative characteristics. It was noted how much the physical and qualitative characteristics of fruits of these plants were varied from one another. The physical attributes, viz., plant height, plant spread, stem girth, fruit weight, number of fruits per plant, number of seeds, seed weight, shell weight, shell thickness, pulp weight, and frost tolerance were calculated by using standard procedures. Fruit yield per tree was calculated by counting the number of fruits per tree and multiplying by the average fruit weight. Total soluble solids were estimated in term of degrees Brix with the help of hand refractometer chlorophyll content in leaves by using protocol of Arnon, 1949. The data were statistically analyzed as per method given by Gomez and Gomez (1984) [2] using completely randomized block design.

Results and Discussion

Growth traits: The data on vegetative growth of different varieties depicted in Table 1 exhibited significant differences. The differences in plant height stem girth, plant spread ranged between 1.92-4.74m, 23.99-40.69cm, 1.53-3.71m, and 1.72-4.40m respectively. The plant height (4.74 m), stem girth (40.69cm), plant spread (E-W-3.71m and N-S-4.40m) were recorded the maximum in SKN-15, while the vegetative characters in terms of plant height (1.92m), stem girth (23.99cm) were measured minimum in SKN-9 and plant spread (EW-1.53m and NS-1.72m) in SKN-3 respectively among the varieties. The difference among SKN-1 to SKN-15 do not differ at all in plant height, stem girth, plant spread (NS) but a significant difference was recorded among SKN-2 to SKN-13; SKN-13 to 14; and SKN-14 to SKN-7. The difference in vegetative growth among the varieties may be due to inherent characters of individual varieties and their acclimatization to varied agro-climatic conditions. The dwarfness is the desirable characters for the high-density planting by accommodating a greater number of plants per unit area which ultimately enhance the productivity. Also reported that the different bael genotypes exhibited variations in their growth behavior under moist conditions of eastern India.

Table 1: Vegetative characters of bael germplasm under semi-arid region of Rajasthan

Germplasm	Vegetative growth				Terminal leaf size (cm)		Lateral leaf size (cm)	
	Plant height (m)	Stem girth (cm)	Plant spread (m), (NS and SW)		Length	Breadth	Length	Breadth
SKN-1	2.99	25.99	2.22	2.57	11.65	6.35	9.31	4.67
SKN-2	4.60	38.59	3.62	4.19	15.17	8.65	9.52	6.77
SKN-3	2.29	24.69	1.53	1.72	10.8	6.35	8.09	4.77
SKN-4	2.99	40.19	1.81	2.5	11.41	6.01	8.15	3.77
SKN-5	2.43	26.39	2.03	2.42	11.98	7.18	7.97	4.25
SKN-6	3.05	35.59	2.26	2.68	13.07	7.25	10.07	5.56
SKN-7	3.33	27.09	2.43	3.01	13.25	6.54	9.26	5.69
SKN-8	3.52	36.69	2.64	2.97	10.95	6.31	7.59	4.55
SKN-9	1.92	23.99	1.54	2.02	12.68	7.19	9.71	5.64
SKN-10	2.10	26.49	1.78	2.09	10.81	7.24	9.56	5.47
SKN-11	2.94	31.99	1.96	2.36	11.66	6.61	8.77	5.53
SKN-12	2.63	26.99	2.76	2.96	11.51	7.43	8.55	4.99
SKN-13	3.73	27.59	3.42	3.58	11.38	6.02	7.59	5.7
SKN-14	4.15	29.69	2.96	3.51	13.07	6.98	8.71	5.57
SKN-15	4.74	40.69	3.71	4.4	15.25	9.45	9.46	6.25
SEm±	0.15	1.60	0.14	0.13	0.47	0.19	0.54	0.30
CD@ 5%	0.44	4.78	0.41	0.36	1.36	0.84	1.55	0.88

Leaf traits: It is evident from the data that the germplasms showed wide differences in their leaf characters under dry land conditions of western India (Table 1). It was noticed that the terminal leaflet size in terms of length (15.25) and breadth (9.45cm) was found maximum in SKN-15 followed by SKN-2, SKN-7, SKN-14, SKN-6 and SKN-9 for length and SKN-2, SKN-12, SKN-6, and SKN-5 with respect to leaflet width, while the minimum length (10.80cm) was recorded in SKN-3 followed by SKN-9, SKN-10 and SKN-4, and minimum breadth (6.01 cm) was recorded in SKN-4 followed by SKN-10 and SKN-11. The lateral leaflet length (10.07cm) and breadth (6.77 cm) was observed the maximum in SKN-6 and SKN-2, respectively, whereas the minimum lateral leaflet length (7.59cm) and breadth (3.77cm) was observed in SKN-8 and SKN-4 respectively followed by SKN-5 and SKN-3 for leaf length and germplasm SKN-5 and SKN-8 with respect to lateral leaflet breadth in all germplasms studied for the leaf morphological characters. The difference between lateral and terminal leaf size among varieties do not differ at all but a significant difference was recorded among SKN-2 to SKN-12 in lateral leaf breadth and; SKN-2 to 7 in; and SKN-14 to SKN-7 in lateral leaf length. Differences in the leaf morphology in different varieties are variety specific characters and adaptability to different agro-climatic conditions. More or less similar variations with respect to leaf characters in various bael genotypes have been reported by Mishra *et al.* (1999) in bael under different agro-climatic conditions.

Table 2: Flowering traits of bael germplasm under semi-arid region of Rajasthan

Germplasm	Flower size (mm)		Bud size (mm)		Petal size (mm)		Pedicel size (mm)	
	Length	Width	Length	Width	Length	Width	Length	Width
SKN-1	14.51	28.84	11	7.35	10.42	7.67	7.64	2.08
SKN-2	19.49	36.22	12.54	9.3	14.4	9.05	9.66	2.94
SKN-3	14.55	28.14	10.79	8.77	12.45	7.57	8.14	2.21
SKN-4	18.91	36.88	11.38	8.67	12.76	7.58	5.65	2.25
SKN-5	12.56	24.1	10.67	8.48	10.58	7.11	4.64	2.53
SKN-6	14.57	28.3	11.61	8.23	12.39	6.99	4.67	2.15
SKN-7	14.61	29.82	10.38	7.29	13.25	8.2	5.53	2.2
SKN-8	17.01	32.77	11.11	7.34	13.45	7.88	8.96	2.14
SKN-9	15.55	31.68	12.66	8.41	10.64	7.63	8.04	2.13
SKN-10	15.63	29.79	11.73	7.71	13.42	7.55	7.74	2.09
SKN-11	15.51	31.29	11.67	8.71	13.03	7.77	7.54	2.17
SKN-12	12.82	26.09	12.48	8.01	13.62	8.23	6.64	2.18
SKN-13	14.57	28.98	11.52	8.23	13.04	7.46	7.92	2.49
SKN-14	16.61	33.09	10.69	8.51	11.82	6.77	7.72	2.19
SKN-15	20.01	38.33	38.45	9.36	14.96	9.28	10.06	2.93
SEm±	0.70	0.98	0.72	0.35	0.76	0.31	0.38	0.12
CD@ 5%	2.03	2.83	2.08	1.01	2.19	1.89	1.09	0.34

Table 3: Flowering characters of bael germplasm under semi-arid region of Rajasthan

Germ.	Flower size (mm)		Filament size (mm)		Anther size (mm)		Pollen		Ovary size(mm)		Style size (mm)		Pollen viability (%)
	Length	Breadth	Width	Length	Width	Diameter	Length	Width	Length	Width	Length	Width	
SKN-1	7.6	5.25	0.6	3.5	0.8	41.31	6.2	3.1	1.1	2.1	2.5	2.1	95
SKN-2	8.6	5.65	0.8	4.5	0.7	45.31	6.6	4.2	1.2	2.5	3.5	2.5	97
SKN-3	8.3	4.55	0.4	4.5	0.8	44.41	5.6	3.2	1.3	2.2	2.5	2.5	93
SKN-4	8.2	4.95	0.5	3.5	0.6	42.51	6	3.3	1.4	2.1	2.8	2.2	95
SKN-5	7.6	4.65	0.6	3.5	0.8	41.31	5.5	3.5	1.5	1.5	2.7	2.1	96
SKN-6	7.6	4.45	0.6	3.5	0.8	40.31	5.7	3.5	1.5	2.1	2.5	2.1	92
SKN-7	6.8	2.85	0.5	4.5	0.7	41.31	5	3.2	1.2	1.6	2.4	2.3	95
SKN-8	7.5	3.65	0.4	3.5	0.5	41.31	4.9	2.5	1.3	1.9	2.9	2.2	93
SKN-9	7.8	3.85	0.6	4.5	0.7	42.61	6.2	3.6	1.2	1.5	2.8	1.9	91
SKN-10	7.6	4.65	0.7	3.5	0.7	43.63	6.6	2.5	1.5	1.9	2.5	1.8	93
SKN-11	7.4	3.65	0.6	4.6	0.6	42.61	5.6	3.5	1.5	2.1	3.1	1.7	94
SKN-12	7.6	4.65	0.5	3.5	0.7	43.51	6.6	3.6	1.5	1.8	2.5	1.9	90
SKN-13	7	3.95	0.5	4.8	0.7	40.52	6.5	3.5	1.4	1.8	2.4	2.1	91
SKN-14	7.5	4.65	0.4	4.6	0.8	41.54	6.6	3.7	1.3	1.7	2.9	2.3	91
SKN-15	8.6	5.65	0.8	5.5	0.8	44.33	6.6	4.5	1.3	2.5	3.5	2.5	97
SEm±	**0.11**	0.07	0.01	0.06	0.01	0.48	0.08	0.04	0.02	0.03	0.04	0.02	1.12
CD@ 5%	**0.31**	0.19	0.03	0.18	0.03	1.38	0.23	0.12	0.05	0.09	0.101	0.06	3.24

Flower characters: The data on the morph metrics of flower of bael germplasms depicted in Table 2 and 3 showed considerable differences for all the floral characters studied. Flower characters with respect to flower length (12.56-20.01mm), flower width (24.1-38.33mm), bud size in terms of bud length (10.38-13.45mm), bud width (7.34-9.36mm), petal length (10.42-14.96mm), petal width (6.77-9.28mm), pedicel length (4.64-10.06mm), pedicel width (2.08-2.94mm), stamen length (6.8-8.6mm), filament length (3.5-5.5mm), width (0.40-0.80mm), anther length (40.45-45.25mm), width (0.50-0.80mm), pollen length (4.8-6.5mm), pollen width(1.5-2.5mm), ovary length (1.1-1.5 mm), ovary width (1.50-2.5), style length (2.4-3.5 mm), width (1.7-2.5 mm).Pollen viability was found to be significantly highest 97% in SKN-15 over SKN-2
and SKN-1, while a non-significant variation was recorded in pollen viability % among these bael varieties. Variations in floral traits in different bael germplasms have been reported by Singh and Mishra (2004) [5] under different climatic conditions of India.

Quantitative fruit traits: It is evident from the data (Table 4) that the values of quantitative characters also varied significantly in different varieties. The maximum yield per plant was recorded in SKN-15 (181.2kg) followed by SKN-2 (143.08kg), SKN-1 (60.37kg), SKN-12 (58.52kg),SKN-7(57.44kg) and they were found at par for fruit yield, whereas fruit yield was recorded minimum in SKN-13 (27.29kg) followed by SKN-9(28.00kg), SKN-8(32.99kg), SKN-6(38.06 kg)in the varieties studied for yield. Fruit weight was recorded the highest in SKB-15(2.93 kg) followed by SKN-2 (1.04 kg), SKN-12 (0.82 kg) and SKN-7 (0.75 kg), whereas the lowest fruit weight was recorded in SKN-13 (0.41 kg) followed by SKN-9 (0.43 kg). Fruit length (18.63cm) was found to be highest in SKN-15 followed by SKN-2 and SKN-12, whereas the same was recorded the lowest in SKN-6 (9.21cm) followed by SKN-10(9.23cm) and SKN-5(9.63cm).The maximum fruit girth (68.9 cm) was exhibited by SKN-15 followed by SKN-5 (49.64 cm) and SKN-2 (49.14 cm), while the minimum fruit girth was observed in SKN-8 (30.41 cm) followed by SKN-4 (30.43 cm), SKN-13(33.44cm),SKN-1(33.55cm), SKN-10 (34.26 cm) and SKN-14 (36.36 cm).

Physical composition: It is evident from the data that the fruit attributes vary greatly in different varieties (Table 4 and 5). Shell weight (391.71 g) was measured conspicuously very high in SKN-15 and the lowest in SKN-4 (119.37g) followed by SKN-1 (145.81g) and SKN-3 (150.21g). Shell thickness (0.34 cm) was recorded maximum in SKN-15 and SKN-11 and the least thickness was observed in SKN-3 & 4 (0.18 cm) followed by SKN-6 (0.19 cm) and SKN-1 (0.20 cm). The pulp content was maximum in SKN-15 (2105.80g) followed by SKN-2 (717.75 g), SKN-4 (535.15g) and the minimum pulp content was obtained in SKN-10 (109.66g). Total number of seeds/fruits (125) was recorded maximum in SKN-11 and 14 followed by SKN-12(116), SKN-9(104), SKN-6 & SKN-13(100) and the minimum numbers of seeds/fruit was observed in SKN-2(68).Seed weight (g) was maximum in SKN-15 (0.32g) followed by SKN-13 (0.28g), SKN-3 (0.27g) and the minimum seed weight was obtained in SKN-8 (0.15g).

Table 4: Physical attributes of bael germplasm under semi-arid region of Rajasthan

Germplasms	Number of fruit/ trees	Fruit yield/ tree (kg)	Fruit weight (kg)	Fruit length (cm)	Fruit girth (cm)	Shell weight (g)	Shell thickness (cm)	Pulp weight (g)
SKN-1	103	60.37	0.65	11.33	33.55	145.81	0.2	427.71
SKNB-2	150	143.08	1.04	15.77	49.14	245.77	0.29	717.75
SKN-3	96	48.18	0.56	10.46	37.46	150.21	0.18	333.31
SKN-4	70	46.75	0.73	9.79	30.83	119.37	0.18	535.15
SKN-5	76	43.32	0.63	9.63	49.64	217.04	0.24	336.48
SKN-6	91	38.06	0.47	9.21	44.29	150.59	0.19	244.93
SKN-7	84	57.44	0.75	10.72	38.9	264.17	0.23	410.35
SKN-8	82	32.99	0.45	10.69	30.41	231.43	0.23	149.72
SKN-9	72	28	0.43	11.33	44.41	244.34	0.24	110.07
SKN-10	84	42.34	0.56	9.23	34.26	378.86	0.25	109.66
SKN-11	93	54.83	0.65	12.3	42.27	194.75	0.34	378.77
SKN-12	78	58.52	0.82	13.38	42.77	214.87	0.25	528.65
SKN-13	74	27.29	0.41	9.63	33.44	220.57	0.26	119.91
SKN-14	87	38.87	0.5	10.53	36.36	235.58	0.26	193.94
SKNB-15	67	181.2	2.93	18.63	68.9	591.71	0.34	2105.8
SEm±	5.20	4.12	0.02	0.51	2.10	10.26	0.01	22.65
CD@ 5%	15.02	11.91	0.06	1.47	6.07	29.65	0.02	65.45

Total seed weight/fruit (g), (13.65 g) was measured conspicuously very high in SKN-14 and SKN-11 and the lowest in SKN-2 (7.35g) followed by SKN-15 (7.65 g), SKN-7 (8.75g) and SKN-5(8.85g). Fiber weight/fruit was maximum in SKN-15 (111.69g) followed by SKN-2 (68.9.g), SKN-12 (54.36) and the minimum fiber weight was obtained in SKN-1(24.6).

Qualitative: It is quite obvious from the data (Table 5) that the different varieties manifested considerable variation in qualitative attribute. The frost tolerant capacity and chlorophyll content were recorded higher (-4℃ and 1.63mg/g fr wt of leaf) in SKN B-15 over SKN B-2(-2℃ and 1.27mg/g fr wt of leaf) and other germplasm of bael. The total soluble solids in pulp were recorded highest in SKN-15(40.76° brix) followed by SKN-2(37.75° brix), SKN-10 (35.86° brix) and SKN-13(35.53° brix) and the lowest TSS of pulp was recorded in SKN-5 (30.45° brix) followed by SKN-3 (31.46° brix) and SKN-7 (31.87° brix), whereas a non-significant variation in the total soluble solids was recorded in among these varieties of bael. Based on the observations, it may be inferred from the study that the bael can successfully be grown commercially with and without irrigation under rainfed conditions of eastern plain zone of India. Among the germplasms, the germplasm namely SKN-15 and SKN-9 for plant height and stem girth; SKN-15 and SKN-3 for plant spread and leaf length; SKN-15 and SKN-4 for leaf breadth; SKN-13 followed by SKN-8 and SKN-6 for lateral leaf length; SKN-4 and SKN-6 for lateral leaf breadth, SKN-15 ranked first for floral biology attributes followed by SKN-5 for flower size, SKN-7 for flower bud, SKN-1 for petal length, SKN-10 for petal breadth,SKN-5 for pedicel length and SKN-1 for pedicel breadth,SKN-7 for stamen size, SKN-14, 3, 2 for filament width, SKN-6, 2 for anther diameter,SKN-10 for pollen width, SKN-2 for ovary width, style size and pollen viability percent.SKN-15 ranked first for yield attributes, yield and quality (except SKN-14, in which total seed weight/fruit was recorded higher) followed by SKN-4 for number of fruit/ tree and yield/tree; SKN-13 for fruit weight; SKN-6 for fruit length; SKN-8 for fruit girth; SKN-4 for shell weight; SKN-3,4 for shell thickness and SKN-10 for pulp weight; SKN-11 for Total number of seed/ fruits; SKN-8 for seed weight; SKN-2 for total seed weight / fruit (g); SKN-1 for fiber weight/ fruit (g) and SKN-5 for TSS Pulp (^{0}Brix).

Conclusion

Based on the overall performance of vegetative growth, leaf, flower, fruit characters and physiological traits of bael germpasms, the SKN-15 and SKN B-2 germplasms were found superior under eastern plain semi-arid environment of India.

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Table 5: Physical attributes and physiological traits of bael germplasm under semi-arid region of Rajasthan

Germplasm	Total number of seed/ fruits	Seed weight (g)	Total seed weight / fruit (g)	Fiber weight/ fruit (g)	T.S.S Pulp (^{0}Brix)	Frost tolerance up to ^{0}C	Chlorophyll content mg/g fr wt of leaf
SKN-1	93	0.23	10.35	24.6	32.5	2^0	1.19
SKNB-2	68	0.20	7.35	68.9	37.75	-2^0	1.27
SKN-3	84	0.27	9.75	30.4	31.46	2^0	1.14
SKN-4	95	0.25	10.35	27.81	33.53	3^0	1.18
SKN-5	82	0.27	8.85	38.4	30.45	2^0	1.22
SKN-6	100	0.21	10.85	37.14	34.47	2^0	1.25
SKN-7	81	0.26	8.75	51.2	31.87	2^0	1.21
SKN-8	93	0.15	10.55	45.7	34.76	2^0	1.18
SKN-9	104	0.18	11.35	37.5	32.79	3^0	1.16
SKN-10	97	0.19	10.55	43.4	35.86	2^0	1.20
SKN-11	125	0.24	13.65	32.67	34.55	2^0	1.21
SKN-12	116	0.22	12.35	54.36	35.28	3^0	1.18
SKN-13	100	0.28	10.75	45.11	35.53	2^0	1.16
SKN-14	125	0.21	13.65	41.36	34.48	2^0	1.20
SKNB-15	74	0.32	7.65	111.69	40.76	-4^0	1.63
SEm±	4.12	0.01	0.21	3.14	1.45	-	0.02
CD@ 5%	11.90	0.03	0.61	9.07	4.19	-	0.06

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