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Characterization of mango hybrids and their parents for vigor, flowering, yield components and biochemical traits

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ABSTRACT

The vigour, blooming, yield, and biochemical features of seventy mango hybrids, including their parents, 'Amrapali' and 'Sensation', were evaluated. The hybrid 'H-13-5' had the greatest plant height (10.11m), where stem girth was maximum in 'H-1-6' (132.21cm), and 'H-13-1' had the largest canopy spread (9.77 m). The hybrid 'H-13-4' exhibited the highest bark-wood ratio (7.59), signifying a higher percentage of mature wood surrounding the entire stem. Hybrid 'H-1-9' had the highest stomatal density (797 stomata/mm^2) as a dwarfing trait. Regarding reproductive characteristics, hybrid 'H-11-4' produced the maximum number of fruits (2.51) per panicle. With a more significant fruit retention percentage of 62%, the hybrid 'H-11-1' showed improved fruit retention on the tree. The tree with the higher fruit output, hybrid 'H-1-8', produced 43 kg of fruit per tree. The hybrid 'H-1-5' produced the maximum size of fruits (317 g/ per fruit). These signify that the resultant hybrids have a lot of potential for future breeding and commercial exploitation because of their advantageous economic traits.

Key words: *Mangifera indica,* Flowering, Genetical studies, Vigour, Yield.

INTRODUCTION

Mango belongs to the genus Mangifera, which consists of around 30 species of tropical fruit trees in the Anacardiaceae family. It has been cultivated in India for over 4000 years, and mango is native to Southeast Asia (Shah *et al.*,13). However, mangoes typically exhibit limited adaptability and specific preferences for growth and yield based on their ecological and geographical conditions (Yadav and Rajan, 17). The available wider genetically diverse gene pools created artificially and naturally are the source of crop improvement. However, in mango breeding, prolonged juvenile phase, extensive heterozygosity, fruit drop and the requirement for large populations pose difficulties for conducting systematic research. During the last 4-5 decades, extensive research on the phenotypic characterization of mango germplasm has significantly contributed to the selection of trait-specific chance seedlings, and only a few hybrids have emerged through hybridization. Recently, ICAR-Indian Agricultural Research Institute (IARI), New Delhi, has developed a large population of mango hybrids from diverse cross combinations. These populations serve as valuable resources for studying the genetics of essential horticultural traits related to dwarfism, regular & precocious bearing, tree vigour, flowering and yield. Keeping this in view, this research work was conducted to identify desirable trait combinations and resultant trait-specific hybrids and understand the inheritance in the progeny population for vigour, flowering, yield, stomatal parameters and other biochemical traits.

MATERIALS AND METHODS

A study was conducted in the Division of Fruits and Horticultural Technology, ICAR-IARI, New Delhi, for two consecutive years (2021 and 2022). The 70 bi-parental progenies and their parents ('Amrapali' and 'Sensation') were studied for tree vigour, flowering, yield, stomatal number and biochemical parameters (Table 1). The experiment was conducted in Randomized Block Design (RBD) with three replications. The measurements were recorded with standard procedures like tree volume (Castle, 3) and panicle emergence on bearing shoots using a rating system (Rathore, 12); the flower sex ratio was calculated by dividing the number of hermaphrodite flowers by number of male flowers, floral malformation was calculated by dividing the number of malformed panicles per tree to the total number of panicles per tree. The number of fruits was counted on 10 panicles in all four directions and expressed as fruit set per panicle. Fruit set and fruit retention of progenies and their parents were recorded on ten panicles in all four directions at 20, 40, 60 and 80 days after flowering. The fruit maturity was adjudged by the Specific gravity method, total fruit yield per tree and

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the yield efficiency was calculated by dividing yield by canopy volume.

Stomatal density was estimated on the abaxial of leaves using a simple binocular microscope (Cahyanto *et al.*, 2). Fully matured strong vegetative shoots were used for bark-wood ratio estimation (Damour and Normand, 5). The total phenolic content in terminal buds was estimated by the Folin-Ciocalteu method (Singleton and Rossi, 14). The data were statistically analyzed using the RBD with Windostat software ver.9.30. Sr.oftware. The recorded data was further analyzed to calculate mean, minimum, maximum, and standard errors, as suggested by Panse and Sukhatme (10).

RESULTS AND DISCUSSION

In the present study, it was found that the heights of the hybrid trees were found to differ significantly (Table 2) and ranged from 2.57 m ('H-1-9') to 10.12 m ('H-4-8') due to the genetic and environmental influences (Singh *et al.*, 16 and Kumar *et al.*, 8). The hybrid 'H-13-1' displayed the widest canopy spread (9.77 m) from north to south. In comparison, 'H-16-1' showed the shortest spread (1.41 m) and 'Sensation' had the largest canopy spread (7.83 m), and 'Amrapali' had the narrowest (4.86 m). A similar wider canopy was also reported by Chandra *et al.* (4). In line with earlier studies by Gautam *et al.* (6) and Kumar *et al.* (8), stem girth increased with tree age as it was highest in 'H-1-6' (132.21cm) and lowest in 'H-9-5' (16.77cm) (Table 3). This rise is probably due to a combination of cambial activity, secondary growth, and the slow accumulation of biomass in the stem. Fresh bark-wood weight ratio also differed; 'H-1-1' weighed the least (4.25) and 'H-13-4' the most (7.59). The ratio of bark to wood can affect fruit

Table 1. List of parental progenies and their parents.

S. No.	Hybrids	Age group (Years)	S. No.	Hybrids	Age group (Years)	S. No.	Parent/hybrid	Age group (Years)
1	H-1-16	7 to 10	26	H-3-6	11 to 20	51	H-1-13	21-30
2	H-7-9		27	H-3-9		52	H-1-14	
3	H-1-9		28	H-3-8		53	H-3-7	
4	H-7-2		29	H-11-2		54	H-3-11	
5	H-9-5		30	H-11-4		55	H-3-14	
6	H-16-1	11 to 20	31	H-11-5		56	H-1-8	
7	H-16-3		32	H-12-3		57	H-1-3	
8	H-22-1		33	H-12-4		58	H-1-5	
9	H-18-4		34	H-4-8		59	H-3-3	
10	H-7-1		35	H-11-1		60	H-3-4	
11	H-16-2		36	H-11-6		61	H-4-2	
12	H-22-2		37	H-12-1		62	H-4-3	
13	H-6-9		38	H-12-5		63	H-1-6	
14	H-6-10		39	H-12-6		64	H-4-1	
15	H-17-1		40	H-12-8		65	H-7-4	
16	H-17-3		41	H-12-10		66	H-3-2	
17	H-17-4		42	H-12-11		67	H-1-1	>30
18	H-18-2		43	H-4-7		68	H-13-1	
19	H-18-3		44	H-6-2		69	H-13-4	
20	H-19-1		45	H-9-4		70	H-13-5	
21	H-4-6		46	H-9-1		71	Amrapali (P1)	25 to 26
22	H-3-12		47	H-9-8	21-30	72	Sensation (P2)	30 to 31
23	H-19-2		48	H-4-9				
24	H-15-1		49	H-1-11				
25	H-1-2		50	H-1-12				

Table 2. Tree height, canopy spread and stem girth in mango hybrids and their parents.

Hybrid and Parents	Tree height (m)	Canopy spread NS (m)	Canopy spread EW (m)	Stem girth (cm)	Hybrid and Parents	Tree height (m)	Canopy spread NS (m)	Canopy spread EW (m)	Stem girth (cm)
H-1-16	3.25	2.90	2.99	45.27	H-12-8	6.33	2.85	2.78	76.66
H-7-9	3.18	3.04	2.94	39.31	H-12-10	7.27	6.69	5.20	73.46
H-1-9	2.57	5.27	5.30	33.67	H-12-11	7.22	4.78	4.79	81.61
H-7-2	2.94	2.15	2.09	28.72	H-4-7	8.58	5.21	4.19	95.34
H-9-5	2.79	3.00	3.29	16.77	H-6-2	6.35	3.61	4.09	69.60
H-16-1	2.88	1.41	2.46	23.55	H-9-4	7.19	5.70	4.91	88.96
H-16-3	3.00	2.17	2.09	28.53	H-9-1	7.35	4.88	4.24	81.77
H-22-1	4.35	4.10	3.06	40.70	H-9-8	8.15	8.12	7.70	91.32
H-18-4	5.96	3.17	4.17	42.99	H-4-9	7.79	5.36	6.35	89.38
H-7-1	5.01	3.67	3.66	29.48	H-1-11	8.79	7.57	6.60	94.18
H-16-2	3.66	2.19	2.36	30.55	H-1-12	7.16	5.91	6.21	85.73
H-22-2	4.12	3.83	3.98	31.55	H-1-13	8.69	6.35	6.52	97.18
H-6-9	5.04	3.39	3.10	35.30	H-1-14	7.24	5.42	4.59	91.22
H-6-10	6.00	4.57	3.59	46.30	H-3-7	7.69	4.20	4.36	96.48
H-17-1	3.50	2.95	2.99	34.87	H-3-11	7.57	3.69	4.14	88.79
H-17-3	5.43	4.17	4.23	41.64	H-3-14	8.06	4.62	3.64	78.89
H-17-4	5.38	3.28	5.03	39.32	H-1-8	7.84	6.85	5.79	99.46
H-18-2	6.35	3.88	3.53	53.17	H-1-3	8.89	6.58	5.63	116.22
H-18-3	6.88	3.27	3.95	49.21	H-1-5	7.59	3.94	4.36	89.54
H-19-1	3.70	2.95	2.90	41.50	H-3-3	6.89	4.17	3.68	79.84
H-4-6	3.66	3.17	3.68	38.35	H-3-4	6.77	3.55	3.73	76.71
H-3-12	4.55	2.16	2.49	46.46	H-4-2	7.20	4.47	4.10	81.45
H-19-2	4.25	5.02	4.69	74.92	H-4-3	6.99	4.14	4.10	83.53
H-15-1	6.55	4.91	5.54	61.41	H-1-6	8.89	6.88	5.69	132.21
H-1-2	6.11	3.98	3.89	55.37	H-4-1	7.55	4.20	4.36	96.48
H-3-6	7.10	3.75	3.42	64.41	H-7-4	6.73	3.53	2.82	124.46
H-3-9	5.82	3.26	4.09	39.96	H-3-2	7.54	4.69	4.24	109.17
H-3-8	6.85	3.59	3.13	51.56	H-1-1	8.17	7.57	6.22	104.30
H-11-2	8.16	3.57	4.50	55.68	H-13-1	8.13	9.77	10.11	91.63
H-11-4	6.57	5.01	4.34	49.36	H-13-4	7.96	5.64	5.09	89.65
H-11-5	7.02	6.14	5.73	58.27	H-13-5	10.11	7.89	10.17	121.38
H-12-3	7.14	4.68	4.28	57.36	Amrapali	6.13	4.86	5.45	53.32
H-12-4	6.88	3.42	4.22	54.85	Sensation	9.04	7.83	6.62	121.22
H-4-8	10.12	4.90	4.74	78.29	Mean	6.50	4.57	4.51	68.50
H-11-1	8.88	6.07	5.69	71.33	C.V.	6.68	9.94	9.19	4.73
H-11-6	7.12	5.05	5.01	50.40	S.E.	0.18	0.19	0.17	1.32
H-12-1	7.14	3.60	3.88	79.41	C.D. 5%	0.49	0.52	0.47	3.68
H-12-5	6.57	3.80	4.53	71.38					
H-12-6	7.67	6.33	6.62	89.54					

Table 3. Fruit retention, fresh bark-wood weight, fruits per panicle and yield in mango hybrids and their parents.

Hybrid and Parents	Fruit retention (%)	Fresh bark-wood weight ratio	Fruits/ panicle	Yield per tree (kg)	Hybrid and Parents	Fruit retention (%)	Fresh bark-wood weight ratio	Fruits/ panicle	Yield per tree (kg)
H-1-16	23.44	5.09	0.90	8.31	H-12-8	23.07	4.09	1.50	22.61
H-7-9	23.00	3.85	1.15	15.02	H-12-10	22.13	4.25	1.30	18.22
H-1-9	14.79	5.08	1.15	5.68	H-12-11	19.23	4.72	1.00	16.47
H-7-2	19.62	4.84	0.90	5.37	H-4-7	6.85	7.17	0.50	10.43
H-9-5	11.41	3.67	0.65	2.80	H-6-2	16.23	2.15	0.90	13.08
H-16-1	20.00	3.83	0.60	2.17	H-9-4	12.66	7.17	1.20	14.15
H-16-3	16.47	5.18	1.15	8.28	H-9-1	20.01	3.27	1.08	16.93
H-22-1	22.72	2.69	0.65	21.19	H-9-8	13.87	3.44	1.00	13.84
H-18-4	25.90	2.42	1.20	11.94	H-4-9	5.16	5.20	0.35	18.80
H-7-1	20.84	5.57	1.20	5.85	H-1-11	3.68	3.72	0.50	14.75
H-16-2	20.25	3.16	1.25	7.08	H-1-12	5.42	4.08	0.95	12.40
H-22-2	21.49	4.04	1.50	8.63	H-1-13	11.67	3.56	1.40	17.92
H-6-9	45.87	5.63	0.95	17.95	H-1-14	18.05	5.20	1.60	17.20
H-6-10	36.76	7.50	1.55	13.00	H-3-7	22.19	3.50	1.25	15.98
H-17-1	37.08	3.33	2.10	15.58	H-3-11	14.26	6.25	1.00	8.01
H-17-3	9.74	5.03	0.35	2.63	H-3-14	23.34	3.48	1.30	17.42
H-17-4	10.43	3.94	0.50	3.26	H-1-8	8.21	6.17	2.00	42.96
H-18-2	21.92	4.50	1.55	10.39	H-1-3	6.51	5.50	0.80	20.78
H-18-3	17.92	2.84	1.20	9.42	H-1-5	9.69	7.59	0.80	10.00
H-19-1	18.51	2.83	1.50	12.66	H-3-3	11.31	4.00	1.20	13.47
H-4-6	31.72	3.07	1.30	7.22	H-3-4	4.26	4.13	0.50	4.15
H-3-12	17.47	3.17	1.15	9.95	H-4-2	13.91	3.68	1.30	9.63
H-19-2	31.87	3.25	2.20	13.35	H-4-3	17.26	7.67	1.15	8.05
H-15-1	6.79	2.83	0.53	6.21	H-1-6	16.69	4.75	1.10	8.12
H-1-2	9.24	2.05	0.38	10.00	H-4-1	22.17	7.55	1.25	15.97
H-3-6	8.95	3.47	0.25	18.92	H-7-4	19.25	3.48	1.50	9.82
H-3-9	10.04	4.20	0.43	11.21	H-3-2	17.70	4.58	1.25	10.49
H-3-8	7.49	5.19	1.05	7.29	H-1-1	10.35	4.25	1.80	8.89
H-11-2	14.94	5.08	1.00	6.59	H-13-1	14.87	4.58	0.70	7.71
H-11-4	48.97	6.10	2.51	7.82	H-13-4	13.22	7.59	1.55	21.32
H-11-5	12.15	5.00	0.65	5.38	H-13-5	12.58	7.50	1.60	22.45
H-12-3	21.09	4.25	1.15	12.04	Amrapali	15.34	5.49	0.90	13.35
H-12-4	49.63	3.50	1.70	1.35	Sensation	10.57	7.70	1.10	30.00
H-4-8	38.58	3.93	1.20	10.35	Mean	19.27	4.60	1.13	12.28
H-11-1	50.00	5.90	1.30	11.75	C.V.	41.42	7.09	29.28	23.25
H-11-6	62.06	4.07	1.25	11.48	S.E.	3.26	0.13	0.13	1.17
H-12-1	19.74	4.84	1.10	16.81	C.D. 5%	9.06	0.37	0.38	3.24
H-12-5	24.40	5.50	1.20	10.85					
H-12-6	22.69	3.10	1.55	13.09					

quality and productivity and is crucial for the tree's internal nutrient transfer. A balanced bark-wood ratio is associated with efficient nutrient transfer, resource allocation, and fruit development.

Fruit retention is one of the economic parameters considered for higher yield potential, was found to differ among the hybrids (Table 3), with 'H-11-6' exhibiting the highest percentage (62.06%) and 'H-1-11' the lowest (3.68%). The number of fruits per panicle varied as well, with 'H-11-4' having the maximum (2.51) and 'H-3-6' having the minimum (0.25) (Table 2). The previous findings also support the above findings, which were associated directly with tree age, climatic conditions, and nutrient availability (Singh *et al.*, 15). Fruit yield is the most important economic trait to select a superior mango variety (Table 3). The maximum yield per tree was recorded in hybrid 'H-1-8' (42.96 kg), while 'H-12-4' had the lowest (1.35 kg/tree). The parent 'Sensation' exhibited the highest fruit yield (30.00 kg/tree), while 'Amrapali' had the lowest (13.35 kg). The wider variability for fruit weight was noticed among the available bi-parental population, and hybrid 'H-1-5' produced the largest weight size (317.32 g) and 'H-16-1' the smallest (57.81 g). The maximum yield efficiency was recorded in 'H-7-9' (1.50 kg/m3) and the minimum in 'H-12-4' (0.05 kg/m3). Of the parents, 'Sensation' had the best yield efficiency (0.44), while 'Amrapali' had the lowest (0.41). The above findings are supported by Gupta *et al.* (7) and Bose *et al.* (1) in the 'Amrapali' and 'Sensation' varieties (Table 4).

Stomatal density in mango leaves is reported to be associated with tree stature and drought tolerance (Perwati, 11). Effective gas exchange and controlling water loss and carbon dioxide intake for photosynthesis are made possible by the number of stomata. Based on this theory, it was measured among the all bi-parental population and their parents. It was found that Sensation recorded the highest stomatal density (1125 mm2), while the lowest was recorded in Amrapali (755 mm2) (Plate 1). Among hybrids, 'H-1-9' exhibited the maximum stomatal density (796.95 mm2) and 'H-13-5' (447.45) the lowest (Table 4; Plate 2). The estimated phenol content of the terminal buds of mangoes ranged among hybrids from 3.40 mg/g ('H-4-2') to 8.54 mg/g ('H-3-12'). However, among parents, it was found to be low in 'Amrapali' (7.41 mg/g) as compared to 'Sensation' (4.18 mg/g) (Table 4). This is mainly associated with the age, variety, growth conditions, and vegetative shoots or buds of a tree.

The findings of this study pave the way for identifying potential hybrids generated through hybridization between 'Amrapali' and 'Sensation'. Bi-parental populations that gave rise to new hybrids differ in phenotype and biochemical composition in mango, which will prove to be of immense significance for breeders and help in their efforts to evolve new varieties with better economical traits. The mango hybrid 'H-16-1' found in dwarfing stature displayed the smallest canopy spread, 'H-11-6' gave maximum fruit retention percentage, 'H-1-8' yielded the highest fruits, and 'H-1-5' produced the largest weight under Delhi conditions. Further long-term studies are required to fully understand the genotypic and phenotypic traits to fully tap the potential of resultant hybrids between 'Amrapali' x 'Sensation' considering the critical economic traits regarding tree stature, fruit set, yield and fruit size.

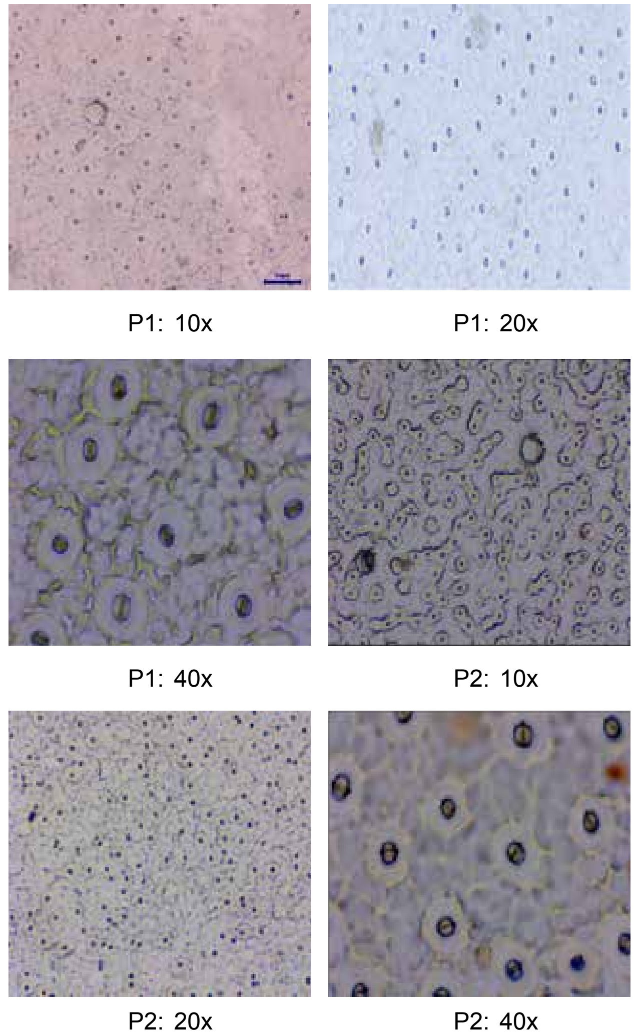
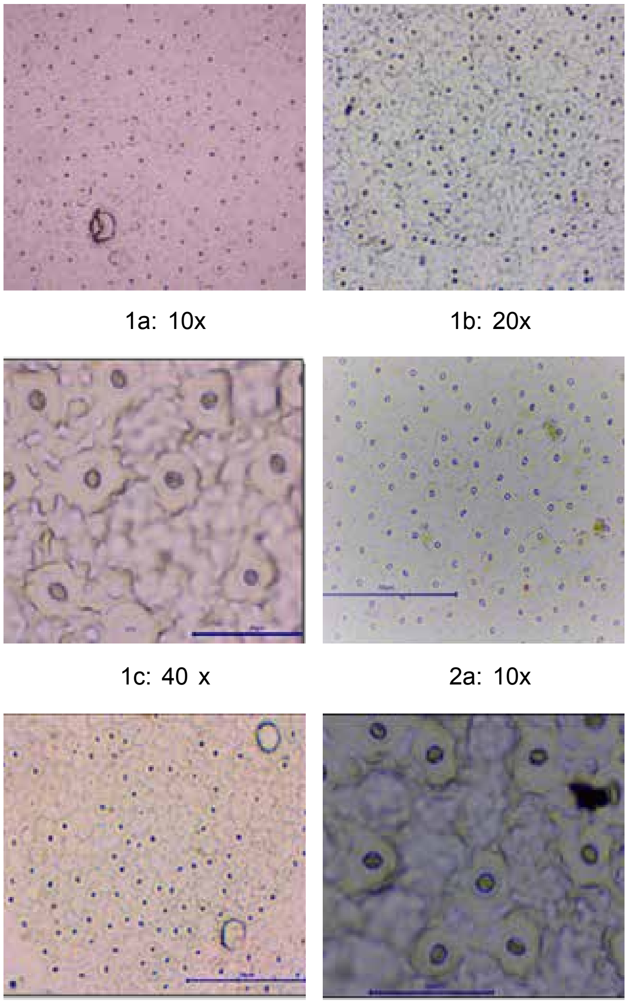


Plate 1. Stomatal density in Amrapali (P_1) and Sensation (P_2) at 10x, 20x and 40 x magnification

Table 4. Fruit weight, yield efficiency, stomatal density and phenolic content in mango hybrids and their parents.

Hybrid and Parents	Fruit weight (g)	Yield efficiency (kg/mm^3)	Stomatal density (∑stomata /mm^2)	Phenol content (mg/g)	Hybrid and Parents	Fruit weight (g)	Yield efficiency (kg/mm^3)	Stomatal density (∑stomata/ mm^2)	Phenol content (mg/g)
H-1-16	187.20	0.84	771.15	6.55	H-12-8	230.00	1.22	627.37	5.11
H-7-9	223.48	1.50	719.30	6.56	H-12-10	184.23	0.40	627.14	5.27
H-1-9	102.33	0.40	796.95	7.55	H-12-11	156.58	0.46	629.93	5.88
H-7-2	117.98	0.82	755.15	6.64	H-4-7	62.75	0.25	663.29	4.68
H-9-5	66.33	0.34	757.50	7.05	H-6-2	174.69	0.51	562.20	4.94
H-16-1	57.81	0.40	664.50	7.97	H-9-4	209.52	0.35	676.30	4.95
H-16-3	207.07	1.24	664.25	7.18	H-9-1	158.39	0.48	588.65	5.24
H-22-1	177.87	1.31	591.50	5.07	H-9-8	133.79	0.21	541.45	4.21
H-18-4	160.92	0.56	621.10	7.30	H-4-9	241.11	0.39	548.40	4.81
H-7-1	157.09	0.31	578.45	8.47	H-1-11	89.40	0.23	643.85	4.63
H-16-2	170.65	0.82	593.50	5.80	H-1-12	131.62	0.27	588.95	5.61
H-22-2	114.22	0.51	682.05	6.40	H-1-13	156.64	0.31	698.85	4.44
H-6-9	142.79	1.05	588.80	5.87	H-1-14	194.48	0.45	593.65	4.34
H-6-10	170.90	0.50	634.40	6.56	H-3-7	184.20	0.46	564.10	5.46
H-17-1	80.60	1.45	694.55	8.00	H-3-11	81.70	0.26	638.00	5.76
H-17-3	138.44	0.11	645.70	6.33	H-3-14	145.57	0.50	616.05	5.10
H-17-4	72.68	0.14	601.60	6.76	H-1-8	175.51	0.83	581.70	5.06
H-18-2	207.07	0.43	675.15	8.05	H-1-3	189.62	0.37	607.85	3.63
H-18-3	181.38	0.36	638.00	6.37	H-1-5	317.32	0.30	590.10	6.05
H-19-1	232.99	1.11	625.20	7.07	H-3-3	139.40	0.48	536.10	5.59
H-4-6	199.11	0.56	594.75	6.11	H-3-4	75.12	0.16	555.00	4.83
H-3-12	187.00	0.90	610.90	8.54	H-4-2	209.75	0.30	605.90	3.40
H-19-2	168.28	0.62	615.95	6.59	H-4-3	208.08	0.27	658.55	3.93
H-15-1	232.50	0.18	616.95	8.44	H-1-6	221.53	0.14	480.10	3.47
H-1-2	193.38	0.40	625.90	7.05	H-4-1	184.20	0.47	550.10	5.06
H-3-6	198.24	0.71	696.65	6.75	H-7-4	184.64	0.44	530.20	5.90
H-3-9	84.40	0.32	676.60	6.97	H-3-2	199.61	0.29	570.50	4.59
H-3-8	148.87	0.30	707.50	5.76	H-1-1	198.09	0.15	519.45	4.03
H-11-2	128.73	0.19	717.65	6.40	H-13-1	169.83	0.09	551.35	3.91
H-11-4	119.02	0.24	693.70	7.26	H-13-4	150.19	0.48	600.75	3.79
H-11-5	157.20	0.12	702.75	7.73	H-13-5	280.85	0.23	447.45	4.00
H-12-3	164.81	0.36	659.20	8.46	Amrapali	184.59	0.41	755.00	7.41
H-12-4	190.53	0.05	674.95	5.79	Sensation	99.58	0.44	1125.00	4.18
H-4-8	143.59	0.20	743.50	5.42	Mean	163.29	0.47	639.18	5.89
H-11-1	130.75	0.22	653.00	6.31	C.V.	15.17	28.49	11.44	7.48
H-11-6	102.79	0.31	678.15	6.82	S.E.	10.11	0.05	29.86	0.18
H-12-1	158.17	0.60	660.95	5.56	C.D. 5%	28.12	0.15	83.04	0.50
H-12-5	132.26	0.38	677.30	6.79					
H-12-6	225.18	0.25	642.89	4.78					



1a: 10x 1b: 20x 1c: 40 x 2a: 10x 2b: 20x 2c: 40 x

Plate 2. Stomatal density of H-1-9 at 10x (1a), 20x (1b) and 40x (1c) followed by H-1-16 at 10x (2a),20x (2b) and 40x (2c).

AUTHORS' CONTRIBUTION

Research conceptualization (MS and NA); Experiment design (JKH, NA, and MS); Experimental materials (MS, AMS, NA, MKV, and GK) contributed; Field/lab experiment execution and data collection (JKH); Data analysis and interpretation (NA, MS, JKH, and MKV); Article preparation (JKH).

DECLARATION

The authors affirm that there is no conflict of interest.

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