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Characterization of *Morinda tomentosa* genotypes under rainfed conditions of western India

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ABSTRACT

A field trial was conducted to characterize *Morinda tomentosa* Heyne ex Roth genotypes which were established during 2009 under field condition during the years 2011-13 at Experimental Farm of Central Horticultural Experiment Station (CIAH-ICAR) Vejalpur, Panchmahals (Godhra), Gujarat. The vegetative morphomatrix in terms of plant height, stem girth, plant spread, number of primary branches and number of secondary branches varied between 3.10-4.70 cm, 19.10-36.08 cm, 2.27-3.87 m, 6.23-13.45 and 12.12-26.00, respectively, whereas leaves morphology, viz. leaf length, breadth, petiole length and vein pairs ranged between 15.00-25.00 cm, 8.00-16.50 cm,1.25-2.29 cm and 7.43-11.33 per leaf, respectively. Yield /plant during 3rd year varied between 3.50-9.41 kg being highest in CHESN 1 and the lowest in CHESN 21 in all the evaluated genotypes. The quantitative fruit characters in terms of fruit weight, length, breadth, number of pyrines, number of seed/fruit and fresh weight of seed ranged between 19.20-47.10 g, 2.49-4.80 cm, 2.34-3.98 cm, 10.95-23.95, 25.17-50.65 and 0.06-0.11 g, respectively. Variations in values of TSS, pH, vitamin C and acidity, protein, phenols, tannins, Ca, K, Na, and Zn ranged between 6-12^{0}brix, 3.50-7.00, 21.15-40.15 mg/ 100g, 1.16-1.51 per cent, 0.09-0.29 g, 11.12-20.05 mg, 0.25-0.46 g, 90.10-102.00 mg, 36.12-49.92 mg, 80.16-93.90 mg and 0.10-0.29 mg among the genotypes characterized for their biochemical composition. Based on the overall observations, CHESN 1, CHESN 16 and CHESN 31 were found to better with respect to most of the qualitative and quantitative characters than rest of the genotypes evaluated under rainfed conditions of western India.

Key words: Evaluation, Genotypes, *Morinda tomentosa*, Morphomatrix, Quantitative

Morinda spp. are an important group of medicinal plants belonging to family Rubiaceae and the various species of the genus are found growing naturally in the forest area, road sides, bunds and neglected land in Gujarat with wide range of variability owing to its wider adoptability to fragile agro-climatic conditions. *M. tomentosa* Heyne ex Roth, a close ally of *M. citrifolia*, is evergreen, small and hardy tree, having capacity to adapt itself successfully in a wide range of habitat from arid, semi-arid to mesophytic conditions (Bermer and Menon 2002). It is known to bear flowers and fruits throughout the year, but more prominently during rainy season. Majority of this fruit trees are growing wild and are adapted to acidic, alkaline and saline conditions. It is also not exacting in its climatic requirement, adaptable to tropic to subtropics, heavy rainfall to drought prone areas and tolerates waterlogging, severe drought and heavy winds (Jenson *et al.* 2002). Its decoction is used to cure chronic skin infections like boils (Cook 1994). Its various parts are used for different purposes traditionally in tribal farming community and fragrant flowers are offered to Lord Ganesha. In Gujarat and Madhya Pradesh, individuals of *M. tomentosa* are found scattered in patches in almost all over the state mainly in forest areas having wide range of diversity in their morphological traits. The objective of this investigation is to characterize and evaluate various genotypes of *M. tomentosa* for their morphological and qualitative characters.

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MATERIALS AND METHODS

The mean summer temperature was 34.9°C while the mean winter temperature was 21.3°C indicating that the area falls under hyperthermic soil regime. The mean monthly maximum temperature ranges from 26 and 41°C, while the minimum monthly temperature varies between 9°C and 26°C. The area is characterized by semi-arid hot climate. The annual water needed or potential evapotranspiration of the area ranges between 1500 to 1600 mm, whereas actual mean usual precipitation is about 831 mm thus causing an annual water deficit of nearly 769 mm. Rain is confined to mainly three months (July to September) with average rainy days about 29. The soil was analyzed for organic carbon, EC, pH, N, P and K (Bhargava and Raghupati, 1993) and soil bulk density and hydraulic conductivity (Page *et al.* 1982) before the initiation of the experiment. The experimental soil type was characterized

with available N (143.20 kg/ha), P (7.13 kg/ha) and K (131.50 kg/ha) and organic carbon (0.27%), while EC and *pH*, bulk density and hydraulic conductivity of soil were 0.14/dSm, 8.75, 1.44g/cc and 0.26 cm/hr, respectively. The soil depth of experimental field ranged from 0.50 to 0.70 m derived from mixed alluvial basalt, quartzite, granite and layers of limestone. The vegetative parameters were recorded at the end of October and eight mature fruits were randomly collected from all the direction of each genotype to record the qualitative and morphological characters. Total soluble solids and pH of fruits were measured with the help of hand refrectmeter and pH meter, respectively. Biochemical compositions like vitamin C, phenols, tannins and acidity were determined by the methods outlined in AOAC (1980). The pooled data were statistically analyzed as per method given by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Vegetative characters

Results of study revealed wide variability among different *M. tomentosa* genotypes with respect to vegetative

Table 1 Characterization *M tomentosa* genotypes for vegetative an yield attributing characters

Genotypes	Growth habit	Bark colour	Plant height (m)	Stem girth (cm)	Plant spread (E-W)	Plant spread (N S)	No. of primary branch	No. of secondary branch	Fruit yield/ plant (kg)	Fruit weight
CHESN 1	Spreading	Light yellow	4.70	36.08	3.20	3.20	13.45	26.00	9.41	47.10
CHESN 2	Dropping	Grey	3.21	24.05	2.55	2.65	9.95	17.19	5.17	25.82
CHESN 3	Semi-spreading	Blackish grey	3.10	25.12	2.56	2.92	8.86	16.15	6.12	25.17
CHESN 4	Spreading	Light yellow	3.40	27.17	2.90	2.56	8.45	13.20	7.22	27.92
CHESN 5	Dropping	Grey	3.70	31.08	2.39	2.40	6.23	16.13	7.14	25.41
CHESN 6	Upright	Grey	3.20	27.17	3.20	2.72	11.56	22.00	6.25	26.81
CHESN 7	Upright	Blackish grey	4.65	36.08	3.37	2.68	9.78	17.45	6.12	31.35
CHESN 8	Spreading	Light yellow	3.39	27.69	2.71	3.05	7.42	14.19	6.78	25.12
CHESN 9	Semi-spreading	Blackish grey	3.65	30.01	2.62	2.61	7.36	13.00	7.12	28.10
CHESN 10	Upright	Light yellow	3.84	28.99	2.92	3.05	8.49	18.10	5.15	23.00
CHESN 11	Dropping	Grey	3.71	26.08	3.40	3.42	9.23	16.19	5.42	31.26
CHESN 12	Dropping	Grey	3.25	25.00	2.97	2.62	12.41	29.00	5.76	19.92
CHESN 13	Semi-spreading	Grey	4.20	34.82	3.82	3.87	11.00	21.23	7.12	26.61
CHESN 14	Spreading	Light yellow	3.43	23.10	3.58	3.42	7.12	15.58	8.42	22.00
CHESN 15	Dropping	Grey	3.92	33.66	3.12	3.31	9.58	16.45	7.92	18.99
CHESN 16	Semi-spreading	Blackish grey	4.48	33.92	3.68	3.82	12.42	24.37	9.12	44.00
CHESN 17	Dropping	Grey	3.21	29.91	3.47	3.62	6.11	13.56	6.14	23.92
CHESN 18	Upright	Grey	3.99	29.96	2.82	3.10	8.77	14.25	6.98	29.71
CHESN 19	Spreading	Grey	3.78	30.12	2.92	3.05	10.26	20.89	6.12	37.52
CHESN 20	Spreading	Blackish grey	3.40	25.84	3.20	3.04	9.15	16.26	7.28	25.08
CHESN 21	Spreading	Grey	3.27	27.84	3.05	3.10	8.46	17.27	3.50	21.92
CHESN 22	Semi-spreading	Blackish grey	3.46	19.10	2.82	2.99	7.35	15.56	7.18	19.27
CHESN 23	Upright	Blackish grey	3.52	29.40	2.72	2.68	8.48	16.00	6.12	34.66
CHESN 24	Upright	Grey	4.14	19.90	2.81	2.80	8.29	16.90	6.99	34.88
CHESN 25	Semi-spreading	Grey	3.12	29.40	2.79	2.92	7.65	15.08	7.12	33.92
CHESN 26	Dropping	Blackish grey	3.44	19.55	2.81	3.01	8.00	14.12	7.92	20.05
CHESN 27	Semi-spreading	Light yellow	3.42	29.40	2.72	3.23	7.47	15.58	5.99	29.10
CHESN 28	Spreading	Blackish grey	4.00	20.90	2.88	3.68	7.67	14.00	7.15	25.12
CHESN 29	Upright	Light yellow	3.17	30.12	2.79	3.41	9.00	12.20	6.32	30.13
CHESN 30	Upright	Grey	4.27	27.92	2.81	3.08	10.24	20.22	5.58	19.82
CHESN 31	Semi-spreading	Light yellow	4.57	31.42	3.21	3.24	11..55	23.58	8.41	41.82
CHESN 32	Upright	Blackish grey	3.27	27.27	3.59	2.98	6.32	23.54	5.70	25.17
CHESN 33	Spreading	Grey	3.92	33.99	2.42	2.48	9.95	17.36	8.08	27.12
CHESN 34	Upright	Grey	3.65	27.36	2.56	2.92	7.29	12.12	7.00	30.00
CHESN 35	Dropping	Grey	4.10	31.17	2.54	2.60	8.37	19.48	6.72	21.15
CHESN 36	Upright	Light yellow	3.46	23.08	2.38	2.48	11.12	15.59	8.01	19.20
CHESN 37	Spreading	Blackish grey	4.10	27.68	3.44	2.27	9.65	17.12	4.82	25.12
CHESN 38	Upright	Blackish grey	3.26	27.52	2.98	3.01	6.28	19.13	4.29	23.91
CHESN 39	Dropping	Light yellow	3.82	30.12	3.05	3.40	7.99	13.00	7.15	37.10
CD (P = 0.05)			0.37	3.31	0.28	0.29	0.88	1.79	0.64	3.41

Table 2 Leaf morphomatrix of different *M. tomentosa* genotypes

Genotype	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)	Vain pairs/ leaf	Leaf adexial surface	Leaf abexial surface	Leaf apex	Leaf shape	Leaf colour
CHESN 1	23.40	14.25	2.05	10.45	Smooth	Rough with less hairs	Acute	Elliptical	Dark green
CHESN 2	25.50	16.00	2.00	10.10	Smooth Shining	Rough with hairs	Acute	Oval elliptical	Green
CHESN 3	22.17	14.00	1.75	8.75	Smooth	Rough with hairs	acuminate	Elliptical	Green
CHESN 4	21.71	12.50	1.50	9.40	Smooth Shining	Rough with hairs	Acute to acuminate	Elliptical	Green
CHESN 5	23.20	13.20	2.00	10.95	Smooth	Rough with hairs	Acute	Elliptical	Green
CHESN 6	22.47	12.74	1.25	7.43	Smooth	Rough with hairs	acuminate	Elliptical	Green
CHESN 7	25.00	10.18	2.10	10.00	Smooth	Rough with hairs	Acute to acuminate	Elliptical	Dark green
CHESN 8	19.00	09.90	1.37	8.17	Smooth	Rough with hairs	Acute	Oval elliptical	Green
CHESN 9	20.40	13.00	1.98	8.70	Smooth Shining	Rough with hairs	acuminate	Elliptical	Dark green
CHESN 10	24.40	15.00	1.78	11.00	Smooth	Rough less hairs	Acute	Elliptical	Green
CHESN 11	22.17	14.00	1.80	9.15	Smooth	Rough with less hairs	Acute	Elliptical	Green
CHESN 12	15.00	8.00	1.20	7.70	Smooth	Rough with less hairs	acuminate	Elliptical	Green
CHESN 13	23.20	13.20	1.75	9.00	Smooth	Rough	Acute	Elliptical	Dark green
CHESN 14	22.47	12.74	1.90	8.12	Smooth	Rough with hairs	Acute	Oval elliptical	Green
CHESN 15	16.17	8.75	1.45	9.64	Smooth	Rough with hairs	Acute to acuminate	Elliptical	Dark green
CHESN 16	22.40	11.75	2.00	11.33	Smooth Shining	Rough with hairs	Acute	Elliptical oval	Green
CHESN 17	20.40	13.00	1.97	8.40	Smooth	Rough less hairs	Acute	Elliptical	Dark green
CHESN 18	25.25	16.00	1.65	8.00	Smooth	Rough with less hairs	Acute to acuminate	Elliptical	Green
CHESN 19	22.17	14.00	1.42	8.79	Smooth Shining	Rough with hairs	Acute	Elliptical	Green
CHESN 20	17.19	9.00	2.00	8.00	Smooth	Rough with hairs	Acute	Oval elliptical	Green
CHESN 21	23.20	13.20	2.10	8.42	Smooth	Rough with hairs	Acute	Elliptical	Green
CHESN 22	22.47	12.74	2.29	9.00	Smooth	Rough with hairs	Acute to acuminate	Elliptical	Green
CHESN 23	22.00	10.18	1.72	7.90	Smooth	Rough with less hairs	Acute	Elliptical	Dark green
CHESN 24	19.00	15.74	2.10	11.00	Smooth	Rough with hairs	acuminate	Elliptical	Green
CHESN 25	20.40	13.00	1.74	9.43	Smooth	Rough with hairs	Acute to acuminate	Elliptical	Dark green
CHESN 26	23.50	16.50	1.75	8.00	Smooth Shining	Rough with hairs	Acute	Oval elliptical	Green
CHESN 27	22.17	14.00	1.27	8.55	Smooth	Rough with hairs	Acute	Elliptical	Green
CHESN 28	21.71	12.50	2.18	8.50	Smooth	Rough with less hairs	Acute to acuminate	Elliptical	Green
CHESN 29	23.20	13.20	2.22	9.40	Smooth	Rough	Acute	Elliptical	Green
CHESN 30	22.47	12.74	2.20	9.00	Smooth	Rough with hairs	Acute to acuminate	Elliptical	Green
CHESN 31	25.00	13.40	2.25	8.77	Smooth Shining	Rough with less hairs	Acute	Elliptical oval	Dark green
CHESN 32	19.18	11.00	1.70	9.43	Smooth	Rough with hairs	Acute	Elliptical	Green
CHESN 33	20.12	12.56	1.72	8.00	Smooth	Rough with hairs	Acute	Elliptical	Green
CHESN 34	17.15	13.12	1.75	8.55	Smooth Shining	Rough with hairs	Acute to acuminate	Elliptical	Green
CHESN 35	18.65	12.27	2.20	8.50	Smooth	Rough with less hairs	Acute	Elliptical	Dark green
CHESN 36	19.14	13.14	2.21	9.40	Smooth	Rough	Acute	Elliptical	Green
CHESN 37	23.12	15.18	1.80	9.00	Smooth	Rough with hairs	Acute to acuminate	Oval elliptical	Dark green
CHESN 38	17.00	12.00	1.91	8.77	Smooth	Rough with less hairs	Acute	Elliptical	Green
CHESN 39	21.42	11.80	2.05	11.00	Smooth Shining	Rough with hairs	Acute	Elliptical oval	Green
CD (P = 0.05)	6.62	4.13	0.83	1.98					

characters of (Table1). The differences in vegetative characters in terms of plant height, stem girth, plant spread, and number of primary and secondary branches varied between 03.10-4.70 m, 19.10-36.08cm, 2.27-3.87 m, 6.23-13.45 and 12.12-26.00, respectively. The vegetative characters like plant height (4.70 m), stem girth (36.08 cm)

Table 3 Floral biology of *M. tomentosa* genotypes under rainfed conditions

Genotype	No. of flowers /head	Panicle length (mm)	Panicle diameter (mm)	Bud length (mm)	Sepal length (mm)	Petal length (mm)	Stamen number	Stamen length (mm)	Style length (mm)	Flower colour
CHESN 1	24.00	20.15	2.00	14.00	5.00	8.50	6.00	5.13	16.00	white
CHESN 2	15.25	12.00	2.50	12.15	4.00	07.54	6.00	6.24	15.50	Greenish white
CHESN 3	17.47	18.20	1.25	13.23	3.00	09.20	6.00	5.12	14.43	white
CHESN 4	20.05	19.17	2.57	10.12	5.00	07.50	6.00	7.00	15.80	white
CHESN 5	20.25	24.00	2.00	13.00	6.50	08.65	5.00	5.55	14.00	white
CHESN 6	12.25	26.50	1.50	12.65	5.50	09.34	6.00	6.50	15.00	white
CHESN 7	15.15	28.00	2.75	10.46	7.20	07.12	6.00	6.80	18.12	white
CHESN 8	13.23	30.12	3.00	12.45	5.20	08.00	6.00	6.67	15.17	Greenish white
CHESN 9	19.87	21.23	2.05	11.00	5.27	08.08	5.00	5.87	17.15	white
CHESN 10	21.25	25.55	2.45	12.23	4.25	07.53	6.00	5.42	14.18	white
CHESN 11	22.80	26.00	2.95	13.50	5.21	10.00	6.00	5.50	15.00	white
CHESN 12	14.14	27.15	2.65	12.00	5.24	09.27	6.00	6.54	17.12	white
CHESN 13	15.17	14.80	2.57	11.00	3.85	06.75	6.00	6.85	15.17	white
CHESN 14	15.15	13.15	1.95	10.15	4.15	08.50	5.00	6.67	17.10	Greenish white
CHESN 15	17.85	15.67	1.62	12.57	6.40	09.30	6.00	5.87	15.14	Greenish white
CHESN 16	23.14	18.14	1.94	13.15	5.23	07.98	6.00	5.42	16.00	white
CHESN 17	19.05	15.12	1.57	10.65	5.47	08.00	6.00	5.13	14.64	white
CHESN 18	22.27	16.68	2.00	11.95	4.28	09.24	5.00	6.24	15.57	white
CHESN 19	23.14	18.00	2.45	12.00	5.50	09.47	6.00	5.18	14.12	white
CHESN 20	13.45	19.25	2.20	13.22	4.00	08.50	6.00	7.05	15.00	white
CHESN 21	12.14	20.00	2.45	11.00	5.00	08.00	6.00	5.50	17.18	Greenish white
CHESN 22	18.86	22.17	2.22	10.13	4.35	09.00	6.00	6.57	15.17	Greenish white
CHESN 23	16.25	23.12	2.30	11.87	3.89	10.53	5.00	6.82	17.15	Greenish white
CHESN 24	19.45	15.00	2.50	12.77	6.20	10.30	6.00	5.15	17.00	white
CHESN 25	15.45	14.37	2.80	13.52	4.50	09.27	6.00	6.29	16.14	Greenish white
CHESN 26	13.23	15.05	2.45	12.00	5.80	07.00	6.00	5.16	13.65	white
CHESN 27	19.17	19.00	2.84	11.55	6.00	07.90	6.00	7.10	14.50	white
CHESN 28	17.18	25.00	2.50	10.95	5.30	08.50	6.00	5.54	15.00	white
CHESN 29	18.15	22.18	1.97	10.00	6.15	10.27	6.00	6.50	17.12	white
CHESN 30	18.12	23.00	1.82	12.33	5.00	09.67	6.00	6.80	15.17	white
CHESN 31	22.85	24.15	2.48	13.00	5.00	08.67	5.00	6.67	18.00	white
CHESN 32	14.14	30.12	2.50	10.15	4.25	09.30	6.00	5.42	16.00	white
CHESN 33	15.17	21.23	1.25	12.57	5.21	07.98	6.00	5.13	14.64	white
CHESN 34	15.15	25.55	2.57	13.15	5.24	08.00	6.00	6.24	15.57	white
CHESN 35	17.85	26.00	2.00	10.65	3.85	09.24	6.00	5.18	14.12	Greenish white
CHESN 36	22.14	27.15	1.50	11.95	4.15	09.47	5.00	7.05	15.00	Greenish white
CHESN 37	19.05	14.80	2.75	12.00	6.40	08.50	6.00	5.50	17.18	Greenish white
CHESN 38	22.27	13.15	3.00	13.22	5.23	08.00	6.00	6.57	15.17	white
CHESN 39	18.14	15.67	2.50	11.95	5.47	09.00	6.00	6.82	14.00	Greenish white
C D (P = 0.05)	1.52	2.15	2.62	0.26	0.58	0.93	0.65	0.72	1.69	

and plant spread (E-W-3.82 m and N S-3.87 m) were recorded the maximum in CHESN 1 followed by CHESN 7, CHESN 5, and CHESN 16, respectively, while the characters like number of primary branches (13.45) and secondary branches (26.00) were observed highest in CHESN 1, whereas the same were noted lowest in CHESN 5 (6.23) and CHESN 34 (12.12), respectively. Variations in vegetative characters in noni, bael, tamarind and chironji have been reported by earlier workers (Wang *et al.* 2002, Singh *et al.* 2005, Singh and Singh 2006 and Singh *et al.* 2012).

Leaf morphomatrix

The data pertaining to leaf morphology exhibited considerable differences for all the characters studied (Table 2). Leaves were simple opposite, rarely pinnate, verticillate, slightly glossy on adaxial surface, lower surface with pubescent dometia, elliptic or ovate-elliptic in shape, apex obtuse or acuminate margin entire smooth, densely tomentose, stipules membranous, often bifid, lobes connate or triangular, sheathing acute. The leaf length varied from 15.00 cm in CHESN 12 to 25.50 cm in CHESN 2 while leaf breadth varied from 8.00 cm in CHESN 12 to 16.50 cm in

Table 4 Physico-chemical attributes of different *M. tomentosa* genotypes

Genotype	Fruit length (cm)	Fruit breadth (cm)	Pyrines/ fruit	Number of seed/fruit	Seed weight (g)	TSS (%)	pH of fruit juice	Acidity (%)	Vitamin C g/100 ml juice
CHESN 1	4.80	3.91	23.95	48.00	0.07	12.00	5.00	1.27	40.15
CHESN 2	3.52	3.08	17.12	37.00	0.06	08.00	4.7	1.34	33.15
CHESN 3	3.41	3.17	15.17	30.23	0.10	09.00	5.00	1.21	32.00
CHESN 4	3.41	3.25	16.19	36.19	0.06	10.00	4.7	1.16	30.19
CHESN 5	3.44	3.24	15.34	38.40	0.08	09.00	4.85	1.37	36.00
CHESN 6	3.39	3.26	17.27	36.27	0.09	10.00	4.55	1.25	31.45
CHESN 7	3.73	3.52	18.10	45.00	0.08	07.00	3.50	1.42	36.19
CHESN 8	3.37	3.32	14.63	36.00	0.10	09.00	4.68	1.48	35.67
CHESN 9	4.42	3.10	13.00	38.19	0.07	10.00	7.00	1.36	28.63
CHESN 10	3.49	3.15	13.75	28.25	0.08	08.50	5.25	1.31	29.19
CHESN 11	3.65	3.25	17.80	41.00	0.10	07.00	4.72	1.25	31.45
CHESN 12	2.67	2.43	12.37	25.17	0.11	11.00	5.00	1.37	30.79
CHESN 13	3.25	3.15	12.18	27.89	0.07	08.50	4.65	1.42	26.08
CHESN 14	3.45	3.17	14.00	34.00	0.07	08.50	4.20	1.41	38.19
CHESN 15	3.35	2.85	20.25	45.00	0.08	06.00	4.57	1.32	37.00
CHESN 16	4.52	3.92	23.20	42.19	0.09	11.50	4.20	1.21	38.84
CHESN 17	3.61	3.20	17.14	36.00	0.10	10.00	4.30	1.30	30.13
CHESN 18	3.41	3.22	17.15	41.89	0.08	11.25	4.39	1.25	34.00
CHESN 19	3.57	3.35	17.18	49.00	0.10	09.25	4.20	1.42	35.25
CHESN 20	3.23	3.20	14.22	32.17	0.08	09.00	4.73	1.44	37.00
CHESN 21	3.18	3.16	15.60	41.00	0.10	09.00	5.50	1.32	30.00
CHESN 22	2.49	2.34	10.95	29.32	0.07	10.00	4.65	1.18	21.15
CHESN 23	4.21	3.52	17.48	41.85	0.08	12.00	4.30	1.51	22.00
CHESN 24	4.28	3.62	16.28	36.00	0.07	08.50	4.50	1.29	32.18
CHESN 25	4.19	3.41	17.29	34.25	0.09	10.25	4.50	1.35	32.32
CHESN 26	3.42	3.25	15.67	29.00	0.11	08.50	4.35	1.38	22.15
CHESN 27	3.45	3.22	14.40	26.15	0.07	10.00	3.52	1.47	30.19
CHESN 28	3.35	3.34	14.81	29.00	0.08	07.00	4.35	1.35	35.14
CHESN 29	3.45	3.32	14.80	30.15	0.06	10.00	4.60	1.37	35.10
CHESN 30	3.45	3.30	19.52	47.18	0.09	9.00	5.40	1.44	34.00
CHESN 31	4.21	3.98	22.00	40.42	0.07	11.80	3.90	1.30	37.00
CHESN 32	3.54	3.56	16.56	45.62	0.07	09.12	4.35	1.38	31.17
CHESN 33	3.64	3.65	13.54	36.89	0.09	12.00	4.35	1.47	36.00
CHESN 34	3.15	3.48	21.25	48.65	0.10	11.30	4.65	1.38	31.45
CHESN 35	3.89	3.82	19.65	50.12	0.08	11.25	4.20	1.47	33.12
CHESN 36	4.12	3.16	18.63	50.65	0.07	08.25	4.57	1.16	35.12
CHESN 37	3.63	3.68	17.35	39.65	0.09	09.00	4.50	1.37	34.85
CHESN 38	4.11	3.49	13.56	49.26	0.10	09.00	4.50	1.21	33.15
CHESN 39	4.06	3.43	13.85	43.25	0.09	10.50	4.35	1.16	32.00
CD (P=0.05)	0.37	0.34	1.58	3.62	0.007	0.96	0.45	0.12	03.45

CHESN 26. The vein pairs recorded the maximum (11.33) in CHESN 16 and it was recorded minimum (7.43) in CHESN 6. Petiole length varied from1.25 cm to 2.29 cm and it was recorded highest in CHESN 22 and it was lowest in CHESN 6 genotype. Variations in leaf morphology of bael and noni genotypes have been reported by Singh *et al.* (2012) and John Britto (2008).

Floral characters

There were marked variation in average bud length in most of the genotypes (Table 3). The highest bud length was recorded in CHESN 1 followed by CHESN 16 and CHESN 31 whereas shortest bud length was recorded in CHESN 29 followed CHESN 22 and CHESN 14. Number of flowers per head ranged between 12.14-24.00 being highest in CHESN 1 followed by CHESN 16 and CHESN 31, whereas the lowest was recorded in CHESN 21 followed CHESN 6 and CHESN 20. The panicle length ranged between 12.00 mm to 30.12 mm. However, the highest value was observed in CHESN 8 which was closely followed by CHESN 7, CHESN 12 and CHESN 6. Panicle diameter ranged from 1.25 mm to 2.95 mm and it was recorded the maximum CHESN 8 followed by CHESN 11 and CHESN 27 and the same was noted minimum in CHESN 3 followed

by CHESN 6 and CHESN 17. There was variation in sepal length in most of the genotypes and it was recorded the maximum in CHESN 7 followed by CHESN 5, CHESN 24 and CHESN 27, while the same was recorded the minimum in CHESN 3 followed by CHES 13 and CHESN 23. The petal length varied from 7.00 mm to 10.00 mm with the maximum value in CHESN 23 followed by CHESN 24 and CHESN 11. Studies indicate that the numbers of stamens in most of the genotypes were found to be 6 rarely 5. The length of stamen was recorded the maximum in CHESN 27 followed by CHESN 20 and CHESN 4, whereas it was recorded the minimum in CHESN 3 followed by CHESN 17 and CHESN 19 in the genotypes studied. The average length of style was recorded the highest in CHESN 7 closely followed by CHESN 31 and CHESN 21, while the minimum style length was recorded in CHESN 5 followed by CHESN 19 and CHESN 10. The flower colour was white to greenish white in all genotypes. Marked variations in floral traits probably indicate the occurrence of inherent genetic variation among the genotypes (Singh *et al.* 2012). Similar trends with respect to floral biology of bael, tamarind and Chironji have been reported by Singh *et al.* (2007), Singh *et al.* (2008) and Singh *et al.* (2010), respectively under rainfed conditions of western India.

Yield

Average yield/plant/year during 3rd year was recorded the maximum in CHESN 1 (9.41 kg) followed by CHESN 16 (9.12 kg) and CHESN 31 (8.41 kg), while minimum yield was observed in CHESN 21 (3.50 kg) followed by CHESN 38 (4.29 kg) and CHESN 37 (4.82 kg) in all the evaluated genotypes of *M. tomentosa* under rainfed conditions (Table 1).Wide range of variability in the yield of various genotypes of jamun, tamarind and chironji have been reported by Singh and Singh (2005), Singh *et al.* (2007) and Singh *et al.* (2010), respectively under rainfed conditions of western India.

Physico-chemical attributes

It is evident from the data that the fruit attributes vary greatly in different genotypes (Table 1 and 4). Fruit weight was recorded the maximum in CHESN 1 (47.10g) followed by CHESN 16 (44.00g) and CHESN 31 (41.82g) and it was recorded lowest in CHESN 36 (19.20g). Fruit length (4.80 cm) was measured conspicuously highest in CHESN 1 and same was the lowest in CHESN 22 (2.49 cm) followed by CHESN 12 and CHESN 34. Fruit breadth was recorded the maximum in CHESN 31 (3.98cm) and CHESN 16 (3.92 cm) and the least of the same was observed in CHESN 22 (2.34 cm) followed by CHESN 12 (2.43 cm). The number of pyrines/fruit was found maximum in CHESN 1 (23.95) followed by CHESN 16 (23.20) and CHESN 31(22.00) and the same was observed minimum in the genotype CHESN 22 (10.95) followed by CISHN 13 (12.18). Total number of seed per fruit was counted the highest in CHESN 36 (50.65) followed by CHESN 35 (50.12) and CHESN 38 (49.26), whereas lowest number of seeds were recorded in CHESN 12 (25.17).Total fresh seed weight was recorded maximum in CHESN 12 and CHESN 26 (0.11 gm) and minimum in CHESN 2 followed by CHESN 4 and CHESN 29 having 6.00 gm weights of seed. Combi and Ash (1994) also reported variations in the physico-chemical attributes in Fijian medicinal plants.

Table 5 Biochemial variations in *M. tomentosa* genotypes

Genotypes	Protein (g)	Ca (mg)	K (mg)	Na (mg)	Zn (mg)	Tannin (g)	Phenol (mg)
CHESN 1	0.29	101.71	49.92	79.14	0.29	0.25	13.32
CHESN 2	0.25	93.99	40.12	82.41	0.19	0.29	11.12
CHESN 3	0.18	94.12	39.97	84.37	0.21	0.41	11.41
CHESN 4	0.25	95.42	39.47	85.71	0.23	0.38	12.52
CHESN 5	0.16	98.12	41.10	86.81	0.21	0.37	15.71
CHESN 6	0.14	97.70	42.12	87.31	0.18	0.41	17.12
CHESN 7	0.18	97.10	44.11	88.42	0.17	0.40	14.14
CHESN 8	0.13	93.41	42.12	82.99	0.19	0.43	13.31
CHESN 9	0.17	92.44	40.10	92.11	0.24	0.40	13.44
CHESN 10	0.21	99.10	40.97	90.01	0.18	0.37	12.92
CHESN 11	0.25	94.64	41.84	89.12	0.17	0.38	16.91
CHESN 12	0.16	95.72	42.80	87.14	0.18	0.41	13.71
CHESN 13	0.12	97.70	41.11	88.39	0.17	0.44	12.81
CHESN 14	0.11	91.10	39.97	89.92	0.10	0.36	14.21
CHESN 15	0.19	92.70	40.00	87.39	0.14	040	14.81
CHESN 16	0.27	99.21	46.84	81.92	0.26	0.29	15.11
CHESN 17	0.22	92.20	42.48	84.11	0.21	0.38	17.31
CHESN 18	0.18	94.70	37.70	90.49	0.17	0.41	13.44
CHESN 19	0.23	97.10	38.80	84.41	0.12	0.37	12.97
CHESN 20	0.17	96.44	39.99	86.82	0.14	0.46	17.10
CHESN 21	0.24	96.42	37.90	84.91	0.25	0.38	15.01
CHESN 22	0.21	96.51	41.16	91.10	0.17	0.44	16.21
CHESN 23	0.27	99.00	42.10	92.70	0.18	0.39	14.41
CHESN 24	0.18	97.00	41.05	93.90	0.17	0.41	11.71
CHESN 25	0.19	96.12	37.97	91.30	0.20	0.44	16.61
CHESN 26	0.20	97.84	36.12	82.70	0.22	0.40	15.71
CHESN 27	0.12	94.12	38.40	84.49	0.21	0.40	18.30
CHESN 28	0.11	93.84	39.12	82.41	0.21	0.37	19.01
CHESN 29	0.23	93.71	38.52	88.73	0.22	0.43	20.05
CHESN 30	0.21	93.81	37.94	89.90	0.26	0.41	16.12
CHESN 31	0.25	102.00	44.84	80.16	0.28	0.30	13.19
CHESN 32	0.09	98.11	39.91	88.14	0.21	0.36	15.22
CHESN 33	0.22	90.10	39.41	87.59	0.22	0.29	12.91
CHESN 34	0.24	92.70	41.14	88.70	0.18	0.40	16.71
CHESN 35	0.24	92.98	41.20	87.59	0.23	0.36	13.61
CHESN 36	0.17	94.01	41.16	88.01	0.17	0.38	14.12
CHESN 37	0.16	95.05	38.77	89.99	0.19	0.37	16.12
CHESN 38	0.16	94.12	38.60	89.81	0.20	0.41	13.13
CHESN 39	0.13	93.10	39.10	84.12	0.23	0.43	17.71
CD (P=0.05)	0.02	09.35	03.18	08.62	0.02	0.06	01.41

Results of study indicated that the quality attributes of *M. tomentosa* genotypes showed significant differences in their values. Fruit acidity was estimated maximum in CHESN 23 (1.51%) followed by CHESN 8 (1.48%) and CHESN 27 (1.47%) and it was minimum in CHESN 39,

CHESN 4, CHESN 39 and CHESN 36, i.e. 1.16% followed by CHESN 22 (1.18%) and CHESN 38(1.21%). Vitamin 'C' content was estimated the maximum in CHESN 1 (40.15mg/100g) followed by CHESN 16 (38.84 mg/100 gm) and the same was recorded the minimum in CHESN 22 (21.15 mg/100 gm) followed by CHESN 23 (22.00 mg/100 gm). The pH of fruit juice was observed highest in CHESN 9 (7.00) followed by CHESN 21 (5.50) and the lowest was recorded in CHESN 7 (3.50) followed by CHESN 27 (3.52). The total soluble solids was recorded the maximum in CHESN 1 (12°brix) followed by CHESN 31 (11.80°brix) and CHESN 16 (11.50° brix) while the minimum value of the same was noted in the genotype CHESN 15 (6° brix). Variations in the chemical composition of different underutilized fruits have been reported by Singh and Singh (2005) in tamarind, Singh and Singh (2005) in mahua, Su *et al.* (2005) in noni and Singh *et al.* (2006) in chironji under different agro-climatic conditions.

Biochemical constituents

The biochemical composition of *Morinda* fruits consisted of protein, Ca, K, Na, Zn, vitamin C, tannin and phenol varied between 0.09-0.29g, 90.10-102.00 mg, 36.12-49.92 mg, 80.16-93.90 mg, 0.10-0.29, 21.15-40.15 mg, 0.25-0.46 g and 11.12-20.05 mg respectively in different genotypes of *Morinda* (Table 4). The highest content of protein were found in CHESN 1 (0.29g) followed by CHESN 16 and CHESN 23 (0.27 g), whereas minimum in CHESN 32 (0.09g) followed by CHESN 14 (0.11g). The minimum calcium content was observed in CHESN 33 (90.10 mg) and it was maximum in CHESN 31 (102.00 mg), whereas the maximum potassium content was recorded in CHESN 1 (49.92 mg) followed by CHESN 16 (46.84 mg) and CHESN 31 (44.84mg), whereas the minimum of the same was recorded in CHESN 26 (36.12). The Na content was recorded highest in CHESN 24 (93.90 mg) and the same was lowest in CHESN 31 (80.16 mg), respectively. The highest content of Zn was found in CHESN 1 (0.29 mg) followed by CHESN 31 (0.28 mg) whereas the minimum in CHESN 14 (0.10 mg). The maximum tannin content was found in CHESN 20 (0.46g) followed by CHESN 13 (0.44g), whereas minimum was observed in CHESN 1 (0.25). However, total phenols varied between 11.12 - 20.05 being highest in CHESN 29 (20.05 mg) and lowest value for the same was observed in CHESN 2 (11.12 mg). Differences in the various biochemical constituents of fruits of *M. tomentosa* genotypes may be genetic in nature rather than due to edaphic or other environmental factors (Shah *et al.* 2006 and Singh *et al.* 2007).

Based on the observations, it may be inferred from the study that the various genotypes of *M. tomentosa* showed morphological variations for most of the characters and it can be grown successfully without irrigation under rainfed conditions of western India. Among the evaluated genotypes, CHESN 1, CHESN 16 and CHESN 31 were found to be superior with respect to yield and quality attributes under rainfed conditions of western India.

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REFERENCES

AOAC. 1980. *Official Methods of Analysis*. Association of Official Agricultural Chemists, Benjamin Franklin Station, Washington, DC.

Bermer B and Manen J F. 2000. Phylogeny and classification of subfamily Rubioideae (Rubiaceae). *Plant Systematic and Evolution* 225:43–72.

Bhargava B S and Raghupati H B. 1993. Analysis of plant material for macro and micro nutrients. *Methods of Analysis of Soil Plant Water and Fertilizer*, pp 49-82. Tondon (Ed). Fertilizer Development and Consultation Organization, New Delhi.

Cambie R and Ash J. 1994. *Fijian Medicinal Plants.* CSIRO, Australia.

Cooke T H. 1908. *The Flora of Presidency of Bombay*, Vol II, p 43. Calcutta.

Gomez K A and Gomez A. 1984. *Statistical Procedure for Agricultural Research,* 2nd Edn., John Wiley and Sos Inc., New York.

Jenson S, Robbrecht E, Beeckmasn H, Kanomi A and Puff C. 2002. A survey of the systematic wood anatomy of Rubioidae (Rubiaceae). *Journal of Economic and Taxonomic Botany* 7:389–97.

John Britto S Sj. 2008. A review of the taxonomy of *Morinda* L. Rubiaceae. *International Journal of Noni Research* **3** (1-2): 60–74.

Page A L, Miller R H and Keeney D R. 1982. *Method of Soil analysis, Part 1&2, Chemical and Microbial Properties.* American Society of Agronomy, Madison, Wiscosin, USA.

Shah A, Kumar S and Gupta D K D. 2006. Value added products from *Morinda citrifolia* (Indian Noni) - An Overview. (*In*) *National Seminar on Production, Utilization and Export of Underutilized Fruits with Commercial Potentialities*, BCKV, Kalyani, Nadia, West Bengal, India, 22-23 November, pp 91–2.

Singh A K, Singh Sanjay, Joshi H K, Bagle B G and More T A. 2008. Evaluation of bael genotypes for growth behaviour and floral traits under semi-arid ecosystem of Western India. *Horticultural Journal* **21**(3):140–2.

Singh A K, Singh, Sanjay, Singh R S and Joshi H K. 2012. Morphological variability of bael varieties under rainfed conditions of hot semi-arid environment of western India. *Indian Journal of Arid Horticulture* **6** (1-2): 35–7.

Singh D R, Srivastava R C and Sudha R. 2007. Studies on shelf life and biochemical changes of *Morinda citrifolia* L. (Noni) fruits during storage. *Proceedings of National Symposium on Noni for Health and Wellness*, Chennai, 27 and 28 October, pp 84–91.

Singh Sanjay and Singh A K. 2005. Genetic variability in Jamun (*Syzygium cumini*) in Gujarat. *Progressive Horticulture* **37**(1): 144–8.

Singh Sanjay and Singh A K. 2005.Genetic diversity in mahua (*Bassia latifolia*) under semi-arid ecosystem of Gujarat. *Indian Journal of Agricultural Sciences* **75**(8): 519–23.

Singh Sanjay and Singh A. K. 2005. Studies on variability in tamarind (*Tamarindus indica* L) from Gujarat. *Progressive Horticulture* **37**: 280–4.

Singh Sanjay, Joshi H K, Singh A K, Lenin V, Bagle B G.and Dhandar D G. 2007. Reproductive biology of jamun (*Syzygium cuminii* Skeels) under semi-arid tropics of western India**.** *Horticultural Journal* **20** (2): 76–80.

Singh Sanjay, Singh A K, Joshi H K. 2008. Genetic variability for floral traits and yield attributes in tamarind (*Tamarindus indica* L.) *Indian Journal of Horticulture* **65** (3)*:*228–31.

Singh Sanjay, Singh A K and Appa Rao V V. 2006. Genetic diversity in *Chironji* (*Buchanania lanzan* Spreng) under semi-arid ecosystem of Gujarat. *Indian Journal of Agricultural Sciences* **76**: 695–8.

Singh Sanjay, Singh A K, Malik S K and Joshi H K. 2010. Reproductive biology of tamarind (*Tamarindus indica* L.) under semi arid tropics of western India**.** *Indian Journal of Plant Genetic Resources* **23**(2):212–6.

Su B N, Pawlus A D and Jung H A. 2005.Chemical constituents of fruit of *Morinda citrifolia* (Noni) and their antioxident activity. *Journal of Natural Products* **68**: 592–5.

Wang Y, West B, Jenson J, Nowicki D, Su C, Palu A and Anderson G. 2002. *Morinda citrifolia* (Noni): A literature review and recent advances in noni research. *Acta Pharmacological Sinica* **23** (12): 11–27.

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Rainfed agriculture in India: An analysis of performance and implications

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ABSTRACT

The paper examines the trend in the performance of rainfed agriculture in India across major crops during pre- and post-liberalisation period; and ascertains the trend in net income of crop groups of different water requirements in rainfed regions. The major crop groups considered in the analysis are coarse cereals, oilseeds, pulses and cotton. The results indicate that the growth in production of oilseeds and pulses during 1980s and early 1990s weaned out during the subsequent period, probably due to the dilution of some of the policy initiatives like mission mode operation for these crops and adverse terms of trade. However, the yield of most of the crops has increased during the post-liberalisation period. This was also associated with a sharp increase in cost of cultivation. The rate of increase in cost of cultivation was severer for traditional rainfed crops compared to water intensive crops like sugarcane and paddy. Also, the growth in value of production has been lower than the growth in cost of cultivation for the rainfed crops during the post-liberalisation period. The parity of the net income also favoured cultivation of water intensive crops in rainfed lands. Rainfed regions need to focus on yield enhancement through natural resource conservation notably, water; and, incentivise rainfed agriculture through price policies and market opportunities. The study calls for increased investment for rainfed regions for creation of affordable technologies for water conservation and increasing water use efficiency; creation of institutions for better water management and spreading water literacy for sustainable crop production.

Key words: India, Liberalisation, Performance, Rainfed agriculture, Water management

The development issues of rainfed agriculture assume critical importance on account of the slow growth and its implications on livelihood security of significant number of rural poor in India (Rao 2004). About 56 % of the total cultivated area in India falls under rainfed agriculture. The importance of the rainfed agriculture can be gauged from the fact that it contributes to 40 % of the country's food production; accounts for much of the national area under coarse cereals (85%), pulses (83%), oilseeds (70%) and cotton (65%); and holds 60 % of the total livestock populations (Venkateswarlu and Prasad 2012). Even after attaining full irrigation potential, about half of the country's cultivated area would continue to be under rainfed farming. Even at the best possible growth scenario of irrigated agriculture, about 40% of the long term additional foodgrain requirement needs to be met out from the rainfed regions (GoI 2006). Therefore, the developmental needs of the rainfed regions would be of foremost importance in future too. Given the high concentration of rural poverty and backwardness in dry and rainfed regions and the strong linkages of agricultural development on poverty reduction, bringing in a breakthrough in the performance of rainfed agriculture forms an important poverty alleviation strategy in the country.

However, a major concern about the rainfed agriculture in India is the low level of productivity, in fact one among the lowest in dry and rainfed regions in the world (GoI 2011). In this context it is reported that while irrigated crops has registered an improvement in yield and total productivity since the 1960s, those of rainfed crops or dry farming have stagnated. Yet, the average crop yield under rainfed conditions in research and demonstration plots is two to four times higher than the national average crop yields (Lal 2008). Many research and development programmes have been implemented by central and state governments to improve the productivity of rainfed agriculture. However, these programmes often failed to take note of the certain unique characteristics of the rainfed farming system, viz. highly diverse activities/ enterprises; strong linkages with common pool resources; significant role of livestock; and, weak institutional support in terms of markets, credit and inputs (GoI 2011). This has led to missing the context in the development approach, and gradual spread of green revolution type of high intensity agriculture including spread of groundwater based irrigation even in hard rock dry areas of peninsular India (Raina 2006). A notable negative externality of this mismatch has

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