



Morphological assessment to predict genetic variability for leaf yield and component traits in Moringa (*Moringa oleifera*)

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ABSTRACT

Moringa (*Moringa oleifera* L.) is primarily grown for its pod but nowadays it is gaining demands for leaf production. Moringa leaves have immense medicinal and dietary value to supplement nutrients for good health. Therefore, identification and selection of leafy type genotype(s) is imperative. Fifty-two genotypes collected from diversified areas of India were evaluated at Division of Vegetable crops, ICAR-IIHR, Bengaluru from 2018–2020. Analysis of variance for growth and leaf yield traits indicated existence of considerable genetic variability in the gene pool. Magnitude of phenotypic coefficient of variation was higher than its genotypic level for all the traits, indicating the environmental influence on their expression. Higher genotypic and phenotypic coefficient of variation was observed for all the leaf yield traits indicating that higher variability and simple selection would be effective. High heritability was recorded for all growth and leaf yield related traits (60.74–99.89%) except number of primary rachis per leaf (35.66%), suggesting selection based on phenotypic expression is effective for improvement. The estimate of genetic advance as per cent mean value was high for all growth and leaf yield related traits except edible leaf per cent and number of primary rachis per leaf, revealing that additive gene action and selection approach is most helpful for improvement of these characters. High heritability coupled with high genetic advance was observed for stem length, whole leaf weight/shoot and edible leaf weight/shoot which revealed that these characters are under additive gene action and showed higher responses of these trait towards selection.

Keywords: Additive gene action, Genetic advance, Genetic variability, Heritability, Leaf yield, *Moringa oleifera*

Moringa (*Moringa oleifera* L.) belonging to monogeneric family Moringaceae, is a native of Himalayan tract in North-Western part of India. This plant is popularly known as Horse Radish Tree, Moringa Tree, Ben Oil Tree, Miracle Tree and Mother's Best Friend (Stevens *et al.* 2013). India is the largest producer of Moringa in the world and accounts for about 80% of world's supply. It is grown in total area of 43,600 ha with a production of 2.2 million tonnes per annum (APEDA 2018). Though, Moringa is grown for its pods primarily, in recent times it has gained greater momentum for production of leaves (used as fresh, cooked and dry leaf powder) which are being used as an alternative food source to combat malnutrition (Anwar *et al.* 2007, Arabshahi *et al.* 2007). Presently specific variety for

greater leaf yield purpose is absent and in order to develop any cultivar with superior leaf yield, genetic variability is imperative since it is prerequisite to find out the source of variation for leaf yield improvement. Therefore, knowledge of genetic variability is of economic worth in formulating and executing efficient parental selection in the breeding programme and also for exploitation of variability in further crop improvement. Already many reports have been published for existence of genetic variability for different quantitative characters of Moringa indicating a wider variation for duration, pod length, taste, pod colour and yield potential (Suthanthirapandian *et al.* 1989, Raja and Bagle 2008, Raja *et al.* 2013). However, no reports are available for genetic variability of leaf yield related traits to understand its genetic potential for selection of parental lines for leaf yield and quality improvement in Moringa.

MATERIALS AND METHODS

Experimental materials: Moringa genotypes collected from major Moringa growing areas like Southern (Tamil Nadu, Kerala, Karnataka and Andhra Pradesh), Western (Maharashtra) and Eastern part of India (Orissa) were conserved at Field repository, ICAR-Indian Institute

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of Horticultural Research, Hesaraghatta, Bengaluru (Karnataka) and evaluated during 2018–2019. The details of Moringa genotypes and their place of collection have been presented in Supplementary Table 1.

Site Description and Experimental Design: The field experiment was conducted in the already established 2-year-old crop at Experimental Block-II, ICAR-Indian Institute of Horticultural Research, Bengaluru (Karnataka). The genotypes were raised in a randomized complete block design (RCBD) with two replications. The morphological observations were recorded from two-plants/genotypes/replication. Unlike Moringa production for pod purpose, leaf crop is harvested very frequently for its young leaves as leaf yield is determined by harvesting frequency and growth rate of genotype. In each season, leaf harvesting is done after two and half months of pruning of trees (before the onset of flowering). In order to assess the genetic potential for leaf yield at rainy, winter and summer, harvesting was done at three-seasons (September, 2019; December, 2019; March, 2020) and the three season pooled leaf yield is assumed as leaf yield potential of genotype per year. At each season, data was collected for the morphological characters such as growth traits [Stem girth (cm), Number of shoots/plant, Shoot length (cm), Shoot thickness (cm), Internode length (cm), Node to flower initiation, Inflorescence length (cm), Number of primary rachis/leaf, Number of secondary rachis/leaf, Leaf length (cm), Leaf width (cm), Number of leaves/shoot] and leaf yield traits [Whole leaf weight/shoot (g), Edible leaf weight/shoot (g), Edible per cent of leaf (%), Whole leaf yield/plant (kg), Edible leaf yield/plant (kg), Whole leaf yield/ha (t/ha), Edible leaf yield/ha (t/ha)]. Morphological and yield traits are climate dependent, hence the observations made at each season for each traits were pooled and averaged for genetic analysis.

Statistical analysis: The data were analyzed for analysis of variance suggested by Panse and Sukhatme (1967), genotypic (GCV) and phenotypic coefficient of variation (PCV) as per Burton and De-vane (1953). Heritability was estimated according to Falconer (1981) and classified based on Johnson *et al.* (1955). Genetic advance was calculated according to Robinson *et al.* (1949) and genetic advance as per mean was calculated according to Johnson *et al.* (1955).

RESULTS AND DISCUSSION

Mean performance of Moringa genotypes: Analysis of variance (ANOVA) showed highly significant differences ($P < 0.01$) among the genotypes (Table 1) indicating highly heterogeneous nature of 52 Moringa genotypes for all the traits. The descriptive data on range for leaf yield attributing traits showed wider variations for stem length (89.00–231.67 cm) followed by leaf length (36.83–80.67 cm), leaf width (34.67–76.33 cm), number of shoots/plant (8.83–30.83), number of leaves/shoot (12.00–30.83), node to flower initiation (9.42–24.55 cm) and internode length (5.59–12.61 cm). Similarly, wider variation was observed for leaf yield, viz. whole leaf weight/shoot (156.10–745.14 g), edible leaf weight/shoot (93.76–375.43 g), edible per cent of leaf

(45.22–61.72%), whole leaf yield/plant (1.93–17.25 kg), edible leaf yield/plant (0.99–8.69 kg), whole leaf yield/ha (3.08–27.60 t) and edible leaf yield/ha (1.62–13.91 t). This present finding clearly revealed the presence of high genetic divergence in population and possibility to improve the specific trait through direct selection.

Genetic analysis for leaf yield related traits: Genotypic and phenotypic coefficient of variation is categorized as low (<10%), moderate (10–20%) and high (>20%) as suggested by Sivasubramanian and Mahavamenon (1973). The maximum genotypic and phenotypic variance (GV and PV), respectively were recorded for whole leaf weight/shoot (8926.43 and 13094.72), followed by edible leaf weight/shoot (2329.01 and 3749.15), shoot length (590.67 and 817.07), followed by leaf width (75.92 and 95.37), leaf length (62.32 and 81.32). The rest of the characters recorded the moderate to low-level variance (Table 2). Similarly, 10, 7 and 2 out of 19 characters studied had higher, moderate and low GCV and PCV, respectively. Notably, whole leaf yield/plant (44.42 and 47.93), edible leaf yield/plant (42.87 and 46.80), whole leaf yield/ha (44.42 and 47.93), edible leaf yield/ha (42.87 and 46.80), whole leaf weight/shoot (26.32 and 31.88) and edible leaf weight/shoot (25.72 and 32.21) had higher GCV and PCV values. Edible per cent of leaf (5.55 and 7.12) and number of primary branches (5.14 and 8.16) had low-level GCV and PCV (Table 2).

The greater variance of the growth characters among genotypes is resultant of heterogeneous genetic makeup among population, which ultimately controls their morphological manifestation through the activity of endogenous growth regulators (Dhakad *et al.* 2017). The higher PCV than their corresponding GCV for all studied characters revealed the environmental influence on their phenotypic expression which varied according to season. Similar findings were also reported by Selvakumari and Ponnuswami (2017) and Karunakar *et al.* (2018) in Moringa. However, the magnitude of environmental influence was not uniform for every trait as least difference between PCV and GCV was reported for inflorescence length, node to first flower initiation and number of shoots/plant. Similar differential variability was earlier reported by Verma *et al.* (2019) for stem girth and number of branches/plant (high GCV, PCV), and by Karunakar *et al.* (2018) for leaf length with moderate GCV, PCV in Moringa.

The range of heritability was categorized by following method of Johnson *et al.* (1955) such as high (>60%), moderate (31–60%) and low (0–30%) heritability. Considering the growth and leaf yield traits, high heritability estimates were found for all studied characters (>60%) except number of primary rachis/leaf (35.66%), which indicated that phenotypic selection would be effective to improve most of the characters. Notably, the whole leaf and edible leaf yield/plant (>85.0%) along with inflorescence length (99.89%), node to first flower initiation (94.72%) and number of shoots/plant (93.74%) recorded higher values compared to the rest. Similar findings were also reported by Shukla *et al.* (2006) for branches/plant, leaves/plant and

Table 1 Analysis of variances (mean sum of squares) and descriptive analysis for 19 characters in Moringa^a

Parameter/Source of variance	ANOVA				Descriptive analysis			
	Replication	Treatment (Genotypes)	Error	Mean	Range		Genotype	
	1	51	51		Minimum	Maximum	Lowest	Highest
Stem girth (cm)	33.79	112.42**	13.30	33.95	19.95	50.22	IIHR-D-149	IIHR-D-6
Number of shoots/plant	4.11	45.6**	1.47	17.23	8.83	30.83	IIHR-D-46	IIHR-D-109
Shoot length (cm)	532.52	1407.74**	226.40	146.61	89.00	231.67	IIHR-D-59	IIHR-D-4
Shoot thickness (cm)	1.68	2.79**	0.46	7.30	4.72	11.35	IIHR-D-149	IIHR-D-4
Internode length (cm)	0.62	5.69**	0.74	9.45	5.59	12.61	IIHR-D-86	IIHR-D-139
Node to flower initiation	0.76	28.3**	0.77	15.63	9.42	24.55	IIHR-D-125	IIHR-D-109
Inflorescence length (cm)	0.52	59.51**	0.03	21.72	11.03	31.93	IIHR-D-153	Baghya
Number of primary rachis/leaf	0.52	0.42**	0.20	6.46	5.00	7.50	IIHR-D-43	Baghya
Number of secondary rachis/leaf	0.21	1.02**	0.16	5.73	3.83	7.50	IIHR-D-40	IIHR-D-6
Leaf length (cm)	0.13	143.64**	19.00	60.42	36.83	80.67	IIHR-D-59	IIHR-D-131
Leaf width (cm)	0.33	171.3**	19.45	52.94	34.67	76.33	IIHR-D-59	IIHR-D-131
Number of leaves/shoot	0.24	16.8**	1.33	18.32	12.00	30.83	IIHR-D-59	IIHR-D-4
Whole leaf weight/shoot (g)	3600.3	22021.15**	4168.2	358.99	156.1	745.14	IIHR-D-149	IIHR-D-28
Edible leaf weight/shoot (g)	261.84	6141.16**	1357.1	190.12	93.76	375.43	IIHR-D-149	IIHR-D-28
Edible percent of leaf (%)	65.22	22.98**	5.61	53.13	45.22	61.72	IIHR-D-139	IIHR-D-149
Whole leaf yield/plant (kg)	3.29	17.36**	1.32	6.38	1.93	17.25	IIHR-D-149	IIHR-D-28
Edible leaf yield/plant (kg)	0.00	4.55**	0.40	3.36	0.99	8.69	IIHR-D-46	IIHR-D-28
Whole leaf yield/ha (t/ha)	8.42	44.43**	3.37	10.20	3.08	27.60	IIHR-D-149	IIHR-D-28
Edible leaf yield/ha (t/ha)	0.01	112.42**	1.02	5.38	1.62	13.91	IIHR-D-46	IIHR-D-28

^a* Significant at the level P=0.05, ** Significant at the level P=0.01

stem diameter in vegetable amaranth (*Amaranthus tricolor* L.); Shrivastav *et al.* (2017) for inflorescence length having high heritability in *Amaranthus paniculatus*; Karunakar *et al.* (2018) for stem girth, leaf length and Verma *et al.* (2019) for number of branches/plant, stem girth, leaf length in Moringa.

The estimates of genetic advance (Table 2) showed wide range between 0.41 (number of primary rachis/leaf) and 160.69 (whole leaf weight/shoot). Except primary and secondary rachis/plant, edible per cent and stem thickness, all the other growth and yield related traits had high values for genetic advance, thus indicating the presence of additive gene effects for majority of traits. Therefore, these traits are likely to respond favourably to selection. The range of genetic advance as per cent of mean was classified using method developed by Johnson *et al.* (1955) as high (>20%), moderate (11–20%) and low (1–10%). High heritability alone does not guarantee a large improvement from selection unless sufficient genetic gain attributable to additive gene action is present (Mora and Saavedra 2012). High genetic advance per cent of mean was recorded for all the characters under study except a few traits (edible per cent of leaf and number of primary rachis/leaf). This finding clearly indicated that most of these traits are governed by additive gene and thus, selection approach will be helpful for improvement of these characters. Hence, estimation of genetic advance

and genetic gain has an added advantage over heritability as a guiding factor in a selection program to improve any particular desired traits (Xu *et al.* 2017, Li *et al.* 2018). Similar result was reported by Shukla *et al.* (2006) for stem diameter and branches/plant in *Amaranthus tricolor* and also by Akaneme and Ani (2013) for internode length governed by non-additive gene effect in *Amaranthus hybridus*.

Heritability coupled with genetic advance is more reliable in prediction of effectiveness of selection (Dudley and Moll 1969). Accordingly, shoot length, whole leaf weight/shoot and edible leaf weight/shoot revealed its additive gene action and higher responses towards selection. High heritability along with moderate genetic advance were observed for stem girth, inflorescence length, leaf length and leaf width, which indicated predominant role of both additive and non-additive gene action and simple selection offers best choice for their improvement. Moderate heritability and low genetic advance were noted for edible per cent of leaf, indicating the role of dominance and epistasis. Hence, improvement in this trait can be done by recombination. The high heritability associated with high genetic advance as per cent of mean was found for all growth and leaf yield attributing characters except number of primary rachis/leaf and edible per cent of leaf. The high heritability and genetic advance as per cent of mean indicated the possibility of selecting high yielding genotypes from the present

Table 2 Estimates of genetic parameters for various morphological characters^a

Character	GV	PV	GCV	PCV	h ²	GA	GAM
Stem girth (cm)	49.56	62.86	20.74	23.35	78.84	12.88	37.93
Number of shoots/plant	22.06	23.54	27.25	28.15	93.74	9.37	54.35
Shoot length (cm)	590.67	817.07	16.58	19.50	72.29	42.57	29.04
Shoot thickness (cm)	1.16	1.63	14.74	17.42	71.66	1.88	25.71
Internode length (cm)	2.47	3.22	16.63	18.96	76.89	2.84	30.03
Node to flower initiation	13.77	14.53	23.74	24.39	94.72	7.44	47.59
Inflorescence length (cm)	29.74	29.77	25.11	25.12	99.89	11.23	51.69
Number of primary rachis/leaf	0.11	0.31	5.14	8.61	35.66	0.41	6.32
Number of secondary rachis/leaf	0.43	0.59	11.46	13.39	73.30	1.16	20.21
Leaf length (cm)	62.32	81.32	13.07	14.92	76.63	14.24	23.56
Leaf width (cm)	75.92	95.37	16.46	18.45	79.61	16.02	30.25
Number of leaves/shoot	7.74	9.06	15.19	16.44	85.38	5.30	28.91
Whole leaf weight/shoot (g)	8926.43	13094.72	26.32	31.88	68.17	160.69	44.76
Edible leaf weight/shoot (g)	2329.01	3749.15	25.72	32.21	63.80	80.48	42.33
Edible percent of leaf (%)	8.68	14.30	5.55	7.12	60.74	4.73	8.90
Whole leaf yield/plant (kg)	8.02	9.34	44.42	47.93	85.90	5.41	84.81
Edible leaf yield/plant (kg)	2.08	2.48	42.87	46.80	83.90	2.72	80.89
Whole leaf yield/ha (t/ha)	20.53	23.90	44.42	47.93	85.90	8.65	84.81
Edible leaf yield/ha (t/ha)	5.32	6.34	42.87	46.80	83.90	4.35	80.89

^aGV, Genotypic variance; PV, Phenotypic variance; GCV, Genotypic co-efficient of variation (%); PCV, Phenotypic co-efficient of variation (%); h², Heritability (%); GA, Genetic advance; GAM, Genetic advance (per cent of mean)

population (Singh 2009).

Our study concluded that among growth characters, all the leaf yield traits showed high genotypic coefficient of variation, heritability and genetic advance as per cent of mean, thereby indicating additive gene action along with dependency on selection for effective improvement. Based on leaf yield and its component traits, five accessions namely IIHR-D-48, IIHR-4, IIHR-D-131, IIHR-D-109 and IIHR-D-28 were identified as higher leaf yielding genotypes (>9 t/ha) as compared to commercially released varieties of Moringa (PKM-1, PKM-2 and Baghya).

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