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Gene pool conservation and characterization of drumstick (*Moringa oleifera* L.)

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Abstract

The present research work was conducted at the Germplasm Center, Department of Horticulture, Patuakhali Science and Technology University (PSTU), during 2018/2019. The experiment was laid out following a Randomized Complete Block Design (RCBD) with 15 germplasm (treatments) and 4 replications (blocks). The experimental germplasms were Mo-1 to Mo-15. There was found a significant variation among the germplasm in relation to leaf, flower and pod. Better results were obtained from germplasm Mo-2, 14 and 15 in respect of number of leaves, number of leaflets per leaf, leaf length, leaf width, pod length, pod width, seed width, fleshy material weight, yield/tree. Except Mo-1 and Mo-11, all the germplasm had three flowering peaks. Among 15 germplasm 10 of the germplasm produced white colored flower, 3 produced cream-colored flower and 2 produced cream-colored flowers with red streaks. Highest number of leaves (8.25) was recorded in germplasm Mo-2. Longest leaf length was found in Mo-15 (49.75cm) and width was in Mo-14 (21.87cm). Highest number of leaflets per leaf (434.8) was recorded in Mo-15. Maximum pod length (59.83cm) and width (1.8cm) was found in Mo-2. Longest seed length was found in Mo-6 (1.46cm) and width in Mo-15 (0.8cm). The highest number of seeds per pod (24.00) was found in both Mo-8 and Mo-5. The maximum 10-seed weight was found in Mo-9 (4.35 g). Highest fleshy material weight was found in Mo-2 (66.5 g). The maximum total fruit per plant (335.8) and yield (23.51kg) was found in germplasm Mo-2.

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Introduction

As a member of the *Moringaceae* family, *Moringa oleifera* L. is one of the most useful trees currently found throughout the tropics of the world (Jahn, 1988). Immature fruits, flowers and young leaves are used as vegetables separately (Mahatab *et al*., 1987 and Dahot, 1988); Drumstick is cultivated in almost every districts of Bangladesh. It is extensively cultivated in middle and western region of Bangladesh, especially in the division of Khulna, Rajshahi and Dhaka. It can survive without any type of fertilizer, manures, pesticides even watering and weeding, which is very important for the protection of our environment. The plant is usually very slender, with an average height of about 10 meters. The fruits (pods) are long, slender which look like "drumsticks" and hence the popular name (Vinoth and Balamurgan, 2012); The tree has softwood and produces yellowish-white fragrant flowers (Chand *et al*., 2012); The leaves are bipinnate or more commonly tripinnate, up to 45cm long, alternate and spirally arranged on the twigs. The leaflets are finely hairy, green. The fruits are pendulous, linear, three-sided pods with nine longitudinal ridges, usually 20 to 50cm long. (Nautiyal, 1987) stated that, leaves are rich in Vitamin A and C. In a comparison with 7 popular vegetables considered to be good sources of those vitamins, Dahot, 1988: stated that, flowers, and seeds of drumstick contain more of the vitamins. Drumstick leaves and pods are helpful in increasing breast milk in the breastfeeding months. Drumstick is also called superfood for its multi-purpose use including medicinal values. (Murty, 1988) was said that, all parts of the tree are considered medicinal and are used in the treatment of ascites, snake bites rheumatism, and as a cardiac stimulant.

A gene pool is the collection of different genes within an interbreeding population. Conservation refers to protection of genetic diversity of crop plants from genetic erosion. There are two important methods of gene pool conservation viz. *in-situ* conservation and *ex-situ* conservation. The conservation strategies of drumstick in this study were *ex-situ* conservation. *Ex-situ* conservation can be done by field conservation and long-term seed storage/gene bank. Depending upon duration of conservation, long term seed storage is of three types viz. base collection, active collection and working collection. The present study included working collections. In working collection, materials need not to be grown every year. They are stored for short time usually 3-5 years and seeds are stored at low temperatures (5-10°C) (Mahatab *et al*., 1987 and Dahot, 1988); Another approach for conservation is field gene bank. In this approach crops are conserved as living field condition. Both seed gene bank and field gene bank strategies are practical and important methods of gene pool conservation which were followed in this study.

Despite of being very important it isn't cultivated in the low-lying coastal area due to several problems such as water logging condition, in some places soil isn't suitable for drumstick production, there is no systematic production practices, the crop isn't locally available Moreover, very few research have been conducted on the tree, no such step has yet taken to find out the morphological potentiality specially for the south-central region.

In this situation the present study has been conducted to study the morphological characteristics of local drumstick germplasm available in the Germplasm Center, Patuakhali Science and Technology University with the following specific objectives:

i. to find out the morphological variability among the germplasms;
ii. to find out yield variability among the germplasm.

Materials and methods

The present research work was conducted at the Germplasm Center, Department of Horticulture, Patuakhali Science and Technology University (PSTU), during February 2018 to April 2019. In this study 15 germplasm were randomly selected. Data on flowering and fruiting behavior of drumstick were collected from selected 15 drumstick germplasm. Randomly one branch was selected in each direction (North, South, East and West) to collect field data from each plant.

The experiment was laid out following a Randomized Complete Block Design (RCBD) with 15 germplasm

(treatments) and 4 replications (blocks). The collected data from experiment were statistically analyzed by Analysis of Variance (ANOVA) and Duncan's Multiple Range Test (DMRT) was used to compare the means of different parameters.

Fifteen germplasm of drumsticks were selected as the experimental materials for the investigation. These drumsticks were collected from Germplasm Centre, Patuakhali Science and Technology University. All the selected germplasms were six years old tree that's started flowering and fruiting at the age of six months.

Field conservation of drumstick germplasm was done by collection and maintenance of Vegetative propagules of about 27 germplasms at PSTU Germplasm Center was initiated in 2013. Field conservation was made by stem cutting and established plants are maintained in the Germplasm Center. In this research 15 germplasm were selected on the basis of initial flowering, growth and yield performance. In addition, seeds were collected from the selected 15 germplasm and conserved at 15°C temperature in the "Seed Gene Bank" of PSTU Germplasm Center. Among the 15 selected germplasm, 2 germplasm were collected from Rajshahi, 6 germplasm were collected from Sathkhira, 2 germplasm were collected from Jessore, 3 germplasm were collected from Gopalganj and 2 germplasm were collected from Bagerhat.

By using the following methods morphological parameters of the collected drumstick germplasms were studied.

Leaf number was counted. The values of this parameter were expressed in number.
Number of leaflets in every leaf was counted. The values of this parameter were expressed in number.

Length and width of leaf was estimated by a slide calipers and the mean length of leaves in millimeter was determined. The final readings were expressed in centimeter.

Terminal leaf length and width was estimated by a slide calipers and the mean length of terminal leaves in millimeter was determined. The final readings were expressed in centimeter.

Number of buds was counted. The values of this parameter were expressed in number.

Flowering peak was determined by time to time field observation starting from the beginning of anthesis.
Fully matured pods were gradually harvested to find out the mean weight and other measurement of fruits. The weight was taken in gram with the help of a (DJ-220 A, made by Qingdao Dongping Junchuan Industry automation Equipment Co., Ltd.) balance sensitive to ten (10) grams. Pod length and width was estimated by a slide calipers and the mean length of pods in millimeter was determined. The final readings were expressed in centimeter.

Pod stalk length and width was estimated by a slide calipers and the mean length of stalk in millimeter was determined.

Number of fruits in each tree was counted and expressed in number
Fully ripe and dried pods were used to collect seeds. Seeds were separated from the pod by hand. After that the weight of seeds was taken in gram with the help of balance (DJ-220 A, made by Qingdao Dongping Junchuan Industry automation Equipment Co., Ltd.) sensitive to ten (10) grams.

Seed length and width was estimated by a slide calipers and the mean length of seed in millimeter was determined. The final readings were expressed in centimeter. Number of seeds in a pod was estimated by using fully mature dried pods then seed number were counted. The values of this parameter were expressed in number.

Fleshy material was measured from seed-pod weight - seed weight. Fruit and seed color was estimated by using "ON Color Measure" application made by Potato tree soft. Yield per tree was determined by taking weight of all the fruits of a tree and it was expressed askg/plant.

Results and discussion

The results obtained in the present investigation entitled "Gene pool conservation and characterization of drumstick (*Moringa oleifera* L.)" in table for discussion, comprehension and understanding. The results and discussion of the study are presented under the following sub-headings.

Collection and conservation of drumstick germplasm

There was variability in GPS coordination of selected 15 germplasm. Accordingly, passport (Latitude and longitude) data were collected and mentioned in the table 1.

Table 1. Passport data of drumstick germplasm collected from different location in Bangladesh.

Location	Germplasm	GPS Latitude	Longitude
Rajshahi	Mo-1	24º 23´ 22˝ N	88º 38´ 38˝ E
	Mo-2	24º 25´ 59˝ N	88º 32´ 15˝ E
Jessore	Mo-3	23º 13´ 15˝ N	89º 04´ 40˝ E
	Mo-4	23º 08´ 04˝ N	89º 05´ 17˝ E
Sathkhira	Mo-5	22 46´ 59˝ N	89º 06´ 17˝ E
	Mo-6	22º 24´ 32˝ N	89º 04´ 58˝ E
	Mo-7	22º 41´ 10˝ N	89º 10´ 13˝ E
	Mo-8	22º 39´ 33˝ N	89º 03´ 10˝ E
	Mo-9	22º 39´ 14˝ N	89º 02´ 33˝ E
	Mo-10	22º 40´ 56˝ N	89º 03´ 39˝ E
Bagerhat	Mo-11	22º 47´ 05˝ N	89º 47´ 52˝ E
	Mo-12	22º 43´ 55˝ N	89º 47´ 44˝ E
Gopalganj	Mo-13	23º 05´ 50˝ N	89º 55´ 25˝ E
	Mo-14	23º 01´ 17˝ N	89º 57´ 00˝ E
	Mo-15	23º 12´ 32˝ N	89º 51´ 55˝ E

Leaf Characteristics

Number of leaf

Number of leaf varied from 1.5 to 8.25 with an overall mean of 5.53. The maximum numbers of leaf (8.25) was recorded in the germplasm Mo-2 followed by Mo-14 (7.25) which was statistically similar to Mo-15 (7.25), whereas the minimum number of leaf was noted in germplasm Mo-8 (1.5) (Table 2).

Leaf length (cm)

The average leaf length ranged between 13.92cm and 49.75cm with an overall mean of 27.88cm. The best germplasms observed for leaf length were Mo-15 (49.75cm) followed by Mo-14 (46.37cm) and Mo-2 (42.75cm), whereas the minimum leaf length was noted for germplasm Mo-1 (18.92cm) (Table 2). (Sheetal Tak, 2012) recorded average length of leaf ranged from 28.63cm to 66.37cm.

Leaf width (cm)

The average leaf width ranged between 6.2cm and 21.87cm with an overall mean of 12.63cm. The best germplasms observed for leaf width were Mo-14 (21.87cm) followed by Mo-2 (21.75cm) and Mo-15 (19.37cm), whereas the minimum leaf width was noted in case of germplasm Mo-1 (6.2cm) (Table 2).

Table 2. Mean performance of 15 germplasm for different leaf characteristics in drumstick.

Germplasm	No. of leaf	Leaf length (cm)	Leaf width (cm)	Terminal Leaf length (cm)	Terminal Leaf width (cm)	No. of leaflet/ Leaf
Mo-1	6.5bc	13.92i	6.20h	1.62c	1.12c	307.0c
Mo-2	8.25a	42.75c	21.75a	2.40a	1.52a	421.5b
Mo-3	6.5bc	27.20e	11.75cd	1.37d	1.00de	303.3c
Mo-4	3.75f	29.12d	12.12c	1.57c	1.12c	359.5c
Mo-5	5.25e	19.00i	11.25ce	1.67c	1.17c	359.3c
Mo-6	5.25e	21.25h	11.75cd	1.62c	1.10cd	308.0c
Mo-7	4.5ef	29.25d	8.87g	1.22ef	1.07cd	312.5c
Mo-8	1.5g	26.00f	9.87fg	1.10f	1.07cd	306.3c
Mo-9	6.0cd	22.37g	10.75def	1.20ef	1.10cd	311.3c
Mo-10	4.5ef	21.62h	10.75def	1.15ef	0.95ef	305.3c
Mo-11	5.5cde	22.12g	10.25ef	1.25e	0.72h	310.0c
Mo-12	6.0cd	20.75h	11.50ce	1.12ef	0.75gh	288.3c
Mo-13	5.0de	21.75h	11.37cde	1.25e	0.85fg	358.3bc
Mo-14	7.25a	46.37b	21.87a	2.05b	1.40b	430.0a
Mo-15	7.25a	49.75a	19.37b	2.10b	1.35b	434.8a
Mean	5.533	27.88	12.63	1.50	1.08	341.0
CV%	13.31	2.90	6.39	5.36	6.63	12.78
LSD	1.051	1.15	1.15	0.119	0.109	62.20
Level of significance	*	*	*	*	*	*

Common letter(s) within the same column do not differ significantly at 5% level of significance analyzed by DMRT. *=Significant (p≤5%).

Terminal leaf length (cm)

The average terminal leaf length ranged between 1.1cm and 2.4cm with an overall mean of 1.50cm. The best germplasm observed for terminal leaf length were Mo-2(2.4cm) followed by Mo-15 (2.1cm) and Mo-14 (2.05cm), whereas the minimum terminal leaf length was recorded for germplasm Mo-8 (1.1cm) (Table 2). (Daniel *et al*., 2015) found the average terminal leaf length ranged from 11.65mm to 40.80mm.

Terminal leaf width (cm)

The average terminal leaf width ranged between 0.725cm and 1.525cm with an overall mean of 1.088cm. The best genotypes observed for leaf width were Mo-2 (1.525cm) followed by Mo-1. (1.4cm) and Mo-15 (1.35cm), whereas the minimum leaf width was noted for Mo-11 (0.72cm) (Table 2). (Daniel *et al*., 2015) found the average terminal leaf width ranged from 7.98mm to 33.87mm.

Number of leaflet/leaf

Number of leaflets varied from 288.3 to 434.8 with an overall mean of 341. The maximum numbers of leaflets per leaf (434.8) was recorded in the germplasm Mo-15 followed by Mo-14 (430) which was statistically similar to Mo-15. The minimum number of leaflets was noted in Mo-12 (288.3) (Table 2). (Sheetal Tak, 2012) recorded number of leaflet/leaf varied from 188 to 413.33.

Flowering behavior of drumstick

All the genotype showed great variation with respect to flower pattern. Except Mo-1 and Mo-11, all the genotypes had one flowering peaks i.e. January. Ten genotypes produced flower of white color whereas three germplasm Mo-2, Mo-14 and Mo-11 produced cream-colored flowers with red streaks (Table 3). (Mathew, 2002) noticed two flowering peaks i.e. July-August and February-March. Flowering in plants is dependent on climate factors as well as genetic factors. It can be continuous, seasonal or erratic. Continuity of flowering can be due to constancy of environmental conditions or intensity to environmental fluctuations. The present study revealed that flowering time in drumstick was not common but it varied with genotypes. The variations in genetic make-up maybe attributed for this.

Table 3. Flowering behavior of 15 drumstick germplasm.

Germplasm	Flowering peak			Duration of flowering peak			Inflorescene Color
	I	II	III	I	II	III	
Mo-1	Jan	Jul	Sep	Jan-Feb	Jul-Aug	Sep-Oct	CWRS
Mo-2	Jan	---	---	Jan-Feb	---	---	W
Mo-3	Jan	---	---	Jan-Feb	---	---	W
Mo-4	Jan	---	---	Jan-Feb	---	---	W
Mo-5	Jan	---	---	Jan-Feb	---	---	W
Mo-6	Jan	---	---	Jan-Feb	---	---	W
Mo-7	Jan	---	---	Jan-Feb	---	---	W
Mo-8	Jan	---	---	Jan-Feb	---	---	W
Mo-9	Jan	---	---	Jan-Feb	---	---	W
Mo-10	Jan	---	---	Jan-Feb	---	---	W
Mo-11	Jan	Jul	Sep	Jan-Feb	Jul-Aug	Sep-Oct	CWRS
Mo-12	Jan	---	---	Jan-Feb	---	---	W
Mo-13	Jan	---	---	Jan-Feb	---	---	W
Mo-14	Jan	---	---	Jan-Feb	---	---	C
Mo-15	Jan	---	---	Jan-Feb	---	---	C

W, C, CWRS denotes white, creamy and creamy white with red streaks.

Fruiting behavior of drumstick germplasm

All the genotypes showed great variation with respect to fruiting behavior. Out of 15 germplasms,

10 germplasm produced fruit of “greenish brown” color whereas three genotypes viz. Mo-2, Mo-14 and Mo-15 produced “dark green” colored fruit. Two germplasm viz. Mo-1 and Mo-11 produced “brown” colored fruits (Table 4). Similar to fruit color, all the germplasm showed great variation regarding seed color. Out of 15 germplasm, 10 germplasm produced “darkbrown” colored seeds whereas three genotypes viz. Mo-2, Mo-14 and Mo-15 produced “light brown” colored seeds. Two genotypes viz., Mo-1 and Mo-11 produced “reddish brown” colored seeds (Table 3).

Daniel *et al.*, 2015 noticed drumstick germplasm regarding seed color. Out of 30 germplasm 17 germplasm produced "tan" colored seeds whereas 13 germplasm produced "cream" colored seeds.

Table 4. Fruiting behavior of 15 drumstick germplasm.

Germplasm	Fruit color	Seed color
Mo-1	Brown	Reddish brown
Mo-2	Dark green	Light brown
Mo-3	Greenish brown	Dark brown
Mo-4	Greenish brown	Dark brown
Mo-5	Greenish brown	Dark brown
Mo-6	Greenish brown	Dark brown
Mo-7	Greenish brown	Dark brown
Mo-8	Greenish brown	Dark brown
Mo-9	Greenish brown	Dark brown
Mo-10	Greenish brown	Dark brown
Mo-11	Brown	Reddish brown
Mo-12	Greenish brown	Dark brown
Mo-13	Greenish brown	Dark brown
Mo-14	Dark green	Light brown
Mo-15	Dark green	Light brown

Pod length (cm)

The Pod length ranged from 32.13cm to 59.83cm with an overall mean of 49.23cm. The maximum pod length was found in germplasm Mo-2 (59.83cm) followed by Mo-6 (59.63cm) and Mo-5 (58.50cm) which were statistically similar. The minimum pod length was found in Mo-4 (32.13cm) (Table 5). Pod length is an economically important character as it decides the handling, packing and transportation of fruits. (Sheetal Tak, 2012) found the Pod length ranged from 26.70cm to 59.47cm.

Pod width (cm)

The pod width ranged from 1.2cm to 1.8cm with an overall mean of 1.48cm. The maximum pod width was found in germplasm Mo-2 (1.8cm) followed by Mo-3 (1.62cm) and Mo-15 (1.6cm) whereas the minimum pod width was found in Mo-12 (1.2cm) (Table 5). (Mohideen and Shanmugavelu, 1982) stated that girth of *Moringa* fruits ranged from 21.5-42.2cm and 4.3-7.0cm.

Table 5. Mean performance of 15 germplasm for different pod characteristics in drumstick.

Germplasm	Pod length (cm)	Pod width (cm)	Pod stalk length (mm)	pod stalk width (mm)	Seed length (cm)	Seed width (cm)
Mo-1	35.75fg	1.53bc	8.3de	0.405e	0.82de	0.68bcde
Mo-2	59.83a	1.8a	9.93c	0.6a	0.89cde	0.73abc
Mo-3	55.25ab	1.63b	2.75i	0.50cd	0.92cd	0.75ab
Mo-4	32.13g	1.28de	8.8d	0.40e	0.88cde	0.70abc
Mo-5	58.5a	1.53bc	7.78e	0.55abc	0.83cde	0.69bcd
Mo-6	59.63a	1.53bc	6.68f	0.50cd	1.46a	0.68bcde
Mo-7	48.0cd	1.48bc	4.83g	0.56ab	0.97bcd	0.68bcde
Mo-8	57.13a	1.45bcd	6.63f	0.59a	0.95cd	0.77ab
Mo-9	43.58e	1.35cde	4.78g	0.42e	0.99bc	0.70abc
Mo-10	42.7e	1.48bc	4.43g	0.44e	0.83cde	0.68bcde
Mo-11	44.05de	1.45bcd	6.25f	0.58a	0.88cde	0.75ab
Mo-12	37.35f	1.2e	1.3j	0.49d	0.63f	0.58e
Mo-13	51.0bc	1.45bcd	3.6h	0.53bcd	0.75ef	0.59de
Mo-14	55.25ab	1.5bc	11.13b	0.48d	1.11b	0.63cde
Mo-15	58.38a	1.6b	15.5a	0.5cd	0.92cd	0.8a
Mean	49.23	1.48	6.84	0.50	0.92	0.69
CV%	5.81	7.59	7.03	5.51	10.75	8.65
LSD	4.08	0.16	0.68	0.045	0.14	0.90
Level of significance	*	*	*	*	*	*

Common letter (s) within the same column do not differ significantly at 5% level of significance analyzed by DMRT. *=Significant (p≤5%).

Pod stalk length (mm)

The pod stalk length varied from 1.3mm to 15.5mm with an overall mean of 6.84mm. The maximum stalk length was found in germplasm Mo-15 (15.5mm) followed by Mo-14 (11.13mm), whereas the minimum stalk length was found in Mo-12 (1.3mm) (Table 5). (Daniel *et al.*, 2015) recorded the pod stalk length ranged from 59.82mm to 129.92mm.

Pod stalk width (mm)

The pod stalk width varied from 0.40mm to 0.6mm with an overall mean of 0.50mm. The maximum pod stalk width was found in germplasm Mo-2 (0.6mm) followed by Mo-8 (0.59mm) and Mo-11 (0.58mm) which were statistically similar, whereas the minimum stalk width was found in Mo-1 (0.405mm) (Table 5). (Daniel *et al.*, 2015) recorded the pod stalk width ranged from 4.22mm to 8.11mm.

Number of seeds per pod

The Number of seeds per pod ranged from 10.75 to 24.0 with an overall mean 18.8. The maximum number of seeds per pod was found in both germplasm Mo-8 (24.00) and Mo-5 (24.00) followed by Mo-6 (23.00). The minimum number of seeds per pod was found in Mo-4 (10.75) followed by Mo-7 (15.5) (Table 6). (Sadasakthi, 1997) reported that the number of seeds per fruit ranged from 17.53-22.53.

Table 6. Mean performance of 15 germplasm for different pod characteristics in drumstick.

Germplasm	No. of seeds/ pod	10-seed weight (g)	Average fleshy mat. wt. (g)	Single pod wt. (g)	Total fruit per plant	Yield (kg) per plant
Mo-1	18.0de	2.15f	24.5k	28.4h	8.5gh	0.36hi
Mo-2	21.0bc	3.19e	66.5a	73.2a	335.8a	23.51a
Mo-3	20.0cd	4.17bc	57.5d	65.85c	83.75b	3.42b
Mo-4	10.75g	4.13cd	34.75j	39.2g	39.25d	1.21f
Mo-5	24.0a	4.26ab	48.75f	58.97d	33.75e	2.1c
Mo-6	23.0ab	4.18bc	60.75c	70.38b	10.75g	0.73g
Mo-7	15.5f	4.33a	39.25i	45.97f	46.75c	2.1c
Mo-8	24.0a	4.04d	64.0b	73.7a	24.25f	1.64d
Mo-9	17.0ef	4.35a	60.75c	68.15bc	10.0g	0.45h
Mo-10	18.75de	4.20bc	41.75h	49.67e	4.5hi	0.16j
Mo-11	18.0de	4.04d	44.25g	51.53e	4.25hi	0.21ij
Mo-12	17.0ef	4.20bc	45.0g	52.13e	3.5i	0.12j
Mo-13	18.0de	4.18bc	52.5e	60.05d	5.25hi	0.17j
Mo-14	20.0cd	3.25e	60.5c	67.0c	22.0f	1.47e
Mo-15	17.0ef	3.20e	62.75bc	68.2bc	24.0f	1.68d
Mean	18.8	3.86	50.9	58.16	43.75	2.62
CV%	7.51	1.80	3.15	3.15	6.3	4.33
LSD	2.01	0.10	2.29	2.61	3.93	0.16
Level of significance	*	*	*	*	*	*

Common letter (s) within the same column do not differ significantly at 5% level of significance analyzed by DMRT. *=Significant (p≤5%).

Seed length (cm)

The seed length varied from 0.63cm to 1.46cm with an overall mean 0.92cm. The maximum seed length was found in germplasm Mo-6 (1.46cm) followed by Mo-14 (1.11cm), whereas the minimum seed length was found in Mo-12 (0.63cm) (Table 6). (Daniel *et al.*, 2015) recorded seed length varied from 10.21mm to 15.03mm.

Seed width (cm)

The seed width varied from 0.587cm to 0.8cm with an overall mean 0.69cm. The maximum seed width was found in germplasm Mo-15 (0.8cm) followed by Mo-8 (0.77cm) and Mo-11 (0.75cm), whereas the minimum seed width was found in Mo-12 (0.58cm) (Table 5). (Daniel *et al.*, 2015) recorded seed length varied from 8.14mm to 10.98mm.

10-seed weight (g)

10-seed weight of 15 genotypes varied from 2.15g to 4.35g. The maximum 10-seed weight was found in germplasm Mo-9 (4.35g) followed by Mo-7 (4.33g) which were statistically similar. The minimum 10-seed weight was found in Mo-1 (2.15g) followed by Mo-2 (3.19g), Mo-15 (3.20g) and Mo-14 (3.25g) (Table 6). Raja *et al.* (2011) recorded the highest seed weight i.e. 12.8g along with 23.5 seeds per fruit in drumstick. (Sheetal Tak, 2012) found that 10-seed weight of 36 germplasms varied from 2.14g to 6.48g.

Fleshy material weight (g)

The average fleshy material weight varied from 24.5g to 66.5g with an overall mean 50.9g. The maximum fleshy material weight was found in germplasm Mo-2 (66.5g) followed by Mo-8 (64.00g), whereas the minimum fleshy material weight was found in Mo-1 (24.5g) followed by Mo-4 (34.75g) (Table 6).

Single pod weight (g)

The average single pod weight varied from 28.4g to 73.7g with an overall mean 58.16g. The maximum single pod weight was found in germplasm Mo-8 (73.7g) followed by Mo-2 (73.2g) which were statistically similar.

The minimum single pod weight was found in Mo-1 (28.4g) followed by Mo-4 (39.20g) (Table 6). (Suthanthirapandian *et al*., 1989) noted that the fruit weight exhibited wide variation (29-231.5g).

Total fruit per plant

The total fruit per plant varied from 3.5 to 335.8 g with an overall mean 43.75 g. The maximum total fruit per plant was found in germplasm Mo-2 (335.8) followed by Mo-3 (83.75). The minimum total fruit per plant was found in Mo-12 (3.5) (Table 6).

Yield (kg) per plant

The yield varied from 0.12kg to 23.51kg with an overall mean 2.62kg. The maximum yield was found in germplasm Mo-2 (23.51kg) followed by Mo-3 (3.43kg), whereas the minimum yield was found in Mo-12 (0.12kg) followed by Mo-10 (0.16kg) and Mo-13 (0.17kg) (Table 6). (Sherkar, 1993) found that an individual *Moringa* tree can yield 50-70kg of pods.

Conclusions

The present study was undertaken to reveal the information regarding the existing genetic variation in this crop for further improvement. Gene pool is conserved; therefore, it will be easily accessible and cultivable to local people in low-lying coastal area. Total 15 germplasms were evaluated and better results were obtained from germplasm Mo-2, 14 and 15 in respect of number of leaves, number of leaflets per leaf, leaf length, leaf width, pod length, pod width, seed width, fleshy material weight, yield/tree. These Characterization can be help to improve existing germplasm as well as to release new variety.

Abbreviation

Mo.= *Moringa oleifera* L., RCBD = Randomized Complete Block Design

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