The Journal of Agricultural Sciences - Sri Lanka
Vol. 19, No 3, September 2024. Pp 439-451
http://doi.org/10.4038/jas.v19i3.10074

Morphological Diversity Assessment of Local Muskmelon *(Cucumis melo* L.) Germplasm in Bangladesh

N. Jahan[1*], Q.M. Ahmed[1], M.F. Khatun[1] , S. Rahman [1], M.G. Hossain [1], M.R. Islam[1] and N. Jahan[1]

Received: 19th December 2022 / Accepted: 13th April 2024

ABSTRACT

Purpose: *Local muskmelon germplasm is being lost because of genetic erosion caused by the replacement of hybrid varieties, lack of conservation climate change, etc. Particularly, the foremost requisites of the industry for muskmelon is a genetic diversity assessment of landraces for identification and trait improvement. Therefore, this study was conducted to estimate the genetic diversity of muskmelon germplasm*

Research Method: *Forty-two muskmelon (Cucumis melo L.) germplasm was collected from different geographical territories of Bangladesh and was studied to identify the morphological diversity among the germplasm using an augmented design. Thirty-four (34) agro-morphological characters were recorded, of which twenty-eight (28) were scored as qualitative characters and six (6) were measured as quantitative characters.*

Findings: *In qualitative characters, variations in morphometrics were found such as the fruit's shape, and different color patterns of fruit skin and flesh, etc. A maximum coefficient of variation of 73.5 % was estimated in fruit weight. Principal Component Analysis (PCA) of different quantitative traits was used to distinguish muskmelon germplasm. The cumulative percentage of variance reached 75.7% by the first two PCA components. Germplasm RC-186, IAH-194, IAH-207, AHM-15, IAH-197, IAH-345, AC-422, and RAI-239, were divergent from others concerning traits such as early maturity, fruit length, width, and weight. Clustering of accessions by D^2 statistic resulted in five clusters and cluster III was found to be the largest containing twenty-two (22) accessions.*

Value: *This research work will be helpful for the further development of the muskmelon variety and the improvement of specific characters.*

Keywords: *Cluster analysis, Diversity, Muskmelon, PCA, Variation*

INTRODUCTION

Muskmelon (Cucumis melo L., 2n = 24) is a morphologically assorted species belonging to the Cucurbitaceae family (Dildar *et al.*, 2020). It is an economically valuable vegetable crop grown throughout the world (Shivapriya *et al.*, 2021). Muskmelon is a minor but very familiar fruit crop in Bangladesh. Muskmelon plants bear fruit with a variety of shapes and flesh colour and advancing lot of significance owing to high production potentiality, short duration with high dietary value, flavor, and delicacy. It is fitted for cultivation under both rainfed and irrigated conditions around the year (Sunita and Hosakatte, 2013). The center of diversity is in Asia from the Mediterranean Sea to Eastern Asia (Pitrat, 2008; Sebastian *et al.*, 2010). Muskmelon fruits are an utmost healthy food preference due to the presence of ascorbic acid, carotene, folic acid, potassium, and many human health-bioactive compounds. vitamins A, C, β -carotene, carbohydrates, sugars, protein and a very small quantity of vitamins K, B_1, B_2, B_6 and niacin were also found in muskmelon (Janghel *et al.*, 2018).

Plant Genetic Resources Centre, Bangladesh Agricultural Research Institute (BARI), Gazipur-1701, Bangladesh

*nasrin.jahan83@gmail.com

https://orcid.org/0000-0001-5222-9243

Muskmelon is commonly consumed as a fresh fruit, as a salad, as a dessert, or as a component of custard. Immature fruits are eaten as salad and cooked (soup, stew, curry, stir-fry) or pickled. Germplasm helps plant breeders for the creation of new combinations of genes and the selection of crop varieties that are more fitted to the requirements of varied systems of agriculture (Glaszmann *et al.*, 2010). Yildiz *et al.*, 2014 stated that for the accurate identification of local landraces and initial evaluation of genetic resources morphological characterization is an important requirement.

A preliminary characterization and assessment of the genetic diversity of germplasm could be helpful for genetic material utilization in breeding programs. It is also useful for the development of new genetically improved cultivars. In any crop improvement programme, the value of genetic diversity has been emphasized both in self and cross-pollinated crops (Reddy *et al.*, 2012). Before biochemical and molecular characterization, morphological diversity study is mandatory (Bello and Olawuyi, 2015). When a substantial amount of genetic resources is to be evaluated for different traits, then characterization, evaluation, and classification of genetic resources are done by Multivariate procedures (Sabaghnia *et al.*, 2014).

Based on diversity analysis selection of parents for desirable characters and planning of an efficient crop improvement program would be more favorable. Plant Genetic Resource Centre (PGRC), Bangladesh Agricultural Research Institute (BARI) collected and conserved germplasm of muskmelon to protect against genetic loss of important landraces of muskmelon. Therefore, this study has sought to allow estimating the divergence of muskmelon through morphological characters and to notice classes of genetically distinct morphological groups in the studied germplasm for future breeding programs to improve characters.

MATERIALS AND METHODS

Research Site

The experiment was conducted at the research field of PGRC of BARI, Gazipur, Bangladesh during February-June, 2022. The research site is located at 23°59'30.246" N latitude, 90°25'10.5168" E longitudes, and 9 m above sea level. It appears under the 7th agro-climatic zone which was active Brahmaputra-jamuna flood plain of Bangladesh.

Plant Materials

Forty-two (42) germplasm of muskmelon that were collected from different regions of Bangladesh were studied in this experiment. Sources of collection of forty-two muskmelon genetic resources are given in Table 01.

Field Methods

This study was carried out in non-replicated augmented design from February-June, 2022. Seeds were sown on 13th February 2022 in plastic pot and seedlings were transplanted in the field on 13 th March 2022. Plot size was 3 × 4 m and plant spacing was 2 × 2 m. Manures and fertilizers such as 10 ton/ha cowdung, 69 kg N, 35 kg P, 75 kg K, 20 kg S, 5 kg Zn and 3 kg/ha B in the form of Urea, Triple Super Phosphate, Murate of Potash, Gypsum, Zinc sulphate, and Boric acid were put in according to recommended doses (FRG, 2018). Cowdung, TSP, MP, gypsum, zinc sulphate, and boric acid were applied during pit preparation one week after transplanting. 15, 35, 55, and 75 days after transplanting, urea was given in four installments as a top dressing. Normal farm work practices were acted accordingly to have a good crop. For insect control, a pheromone trap was used.

Observation and Data Collections

In this study, forty-two germplasm of muskmelon were characterized morphologically based on twenty-eight (28) qualitative (Table 2, 3 & 4) and six (6) quantitative traits (Table 5) as per minimal descriptor of horticultural crops, Part II (Srivastava, 2001). Length, diameter, and thickness were computed by a digital slide caliper. The weight of fruit and seed was measured by digital balance.

In the frame of frequency distribution, the qualitative parameter was described. Mean, variance, standard deviation, and coefficient of variation i.e. simple descriptive statistics were done for quantitative data. Hierarchical cluster analysis was done by ward D^2 method using R software. Principal component analysis was also done which was performed by Statistical Tool for Agricultural Research (STAR) software. (STAR 2.0.1, 2014).

RESULTS AND DISCUSSION

Morphological characterization is a fundamental tool for providing information on their genetic status to guide conservation and improvement. Variations were

Table 1: Sources or places of collection of forty-two muskmelon germplasm

Sl. No.	Germplasm	Collected location	Geographical location	
			longitude	latitude
1	AC-27	Dhaka	24°01’340” N	90°12’149” E
2	AC-86	Tangail	24°25’535” N	90°11’820” E
3	AC-140	Narayanganj	23°48’140” N	90°42’832” E
4	AC-208	Manikganj	23°54’348” N	90°02’477” E
5	AC-237	Manikganj	23°55’860” N	90°01’536” E
6	AC-303	Dhaka	23°55’826” N	90°04’344” E
7	AC-386	Dhaka	23°40’011” N	90°16’972” E
8	AC-387	Dhaka	23°40’011” N	90°16’972” E
9	AC-388	Dhaka	23°40’011” N	90°16’972” E
10	AC-391	Dhaka	23°38’282” N	90°15’028” E
11	AC-408	Dhaka	23°39’605” N	90°21’566” E
12	AC-422	Dhaka	23°38’282” N	90°15’028” E
13	AHM-15	Pirozpur	22°30’440” N	89°57’502” E
14	AMA-39	Pirozpur	22°30’440” N	89°57’502” E
15	IAH-14	Dhaka	23°43’828” N	90°23’730” E
16	IAH-69	Gazipur	24°05’562” N	90°34’855” E
17	IAH-187	Gazipur	23°59’595” N	90°24’874” E
18	IAH-194	Gazipur	23°59’595”N	90°24’874”E
19	IAH-197	Gazipur	23°59’595”N	90°24’874”E
20	IAH-198	Gazipur	23°59’595”N	90°24’874”E
21	IAH-199	Gazipur	23°59’595”N	90°24’874”E
22	IAH-207	Dhaka	23°43’828”N	90°23’730”E
23	IAH-220	Dhaka	23°43’828”N	90°23’730”E
24	IAH-245	Dhaka	23°43’828”N	90°23’730”E
25	IAH-257	Dhaka	23°38’555”N	90°29’004”E
26	IAH-317	Khagrachari	23°08’07.7"N	91°59’54.8"E
27	IAH-334	Khagrachari	23°08’07.7"N	91°59’54.8"E
28	IAH-345	Khagrachari	23°08’07.7"N	91°59’54.8"E
29	IAH-350	Khagrachari	23°13’19.1"N	92°03’11.7"E
30	RAI-73	Chattagram	22°41’187”N	91°46’506”E
31	RAI-79	Chattagram	22°41’187”N	91°46’506”E
32	RAI-239	Comilla	23°30’838”N	90°52’122”E
33	RAI-240	Comilla	23°30’838”N	90°52’122”E
34	RC-186	Jamalpur	24°55’43.8"N	89°58’06.1"E
35	TRMR-34	Chandpur	23°12’32.8"N	90°40’21.3"E
36	TRMR-36	Chandpur	23°13’11.6"N	90°40’27.9"E
37	TRMR-41	Chandpur	23°13’40.8"N	90°40’00.5"E
38	TRMR-69	Chandpur	23°13’40.8"N	90°40’00.5"E
39	TRMR-81	Chandpur	23°13’43.7"N	90°39’52.7"E
40	TRMR-83	Comilla	23°27’33.7"N	91°15’02.0"E
41	TRMR-149	Comilla	23°28’17.0"N	91°13’46.1"E
42	TRMR-160	Comilla	23°28’17.0"N	91°13’46.1"E

observed concerning different morphological traits to meet the requirement of a plant breeder that manifests the probability of getting desirable plant traits from selective germplasm. An extensive variation is observed in muskmelon so particular concern should be given for trait improvement (Malek *et al.*, 2012).

Qualitative Character

Qualitative traits are regarded as salient markers to describe the physical aspects of a plant (Kurlovich *et al.*, 1998). In this study, a total of twenty-eight (28) qualitative characters including stem colour, leaf outline, leaf shape and lobe, leaf margin dentation, leaf pubescence density and type, leaf colour, leaf

Figure 1: Three types of leaf shape were observed in muskmelon i.e. entire (80.95%), trilobate (16.67%), and Penta lobate (2.38%).

glossiness, prominent of leaf vein, flower color, fruit shape, predominant fruit skin colour, secondary fruit skin colour, primary colour and secondary colour of immature fruit, primary colour of mature fruit, fruit skin hairiness, the shape of fruit ribs, stem end shape, blossom end shape, fruit cracking habit, flesh colour, flesh texture, flesh favor, placenta colour, external aroma and internal aroma were evaluated to know the variation among germplasm. Colour was measured by eye estimate according to the descriptor. Qualitative traits i.e the shape and base of the leaf, leaf surface, leaf apex, margin, and petioles of the leaf, and also growth habit, tendril type, flower type and colour, fruit shape, type, and colour were also recorded by Mercy and Bosa (2013). Dildar *et al.* (2020) recorded data on different morphological characters, viz. color of rind, sutures presence or absence, netting type, color and texture of flesh from seventy muskmelon germplasm. In the stem, leaf, and flower characters, variation was observed for most of the characters except leaf outline, prominent leaf vein, and flower colour. Malek *et al.* (2012) also observed that except for tendrils and flowering habits, all the studied muskmelon germplasm displayed morphological differences for all the traits. All germplasm had broadly ovate leaf lines, present prominent leaf veins, and flower colour (Table 02). Three types of leaf shape were observed i.e entire (80.9%), trilobate (16.6%) and Penta lobate (2.38%) (Fig. 01). In the case of leaf lobes deep germplasm were observed. Malek *et al*. (2012) also observed no leaf lobes for 10 germplasm, shallow for 12 germplasm, intermediate for 29 germplasm, and deep leaf lobes for 16 germplasm. 64.2 % germplasm had weak leaf margin dentation;14.2% germplasm had an intermediate type and 21.4% germplasm had a strong type. Leaf glossiness was glossy for 16 germplasm (38.10%), intermediate for 15 germplasm (35.71%), and dull for 11 germplasm (26.19%).

In fruit character, there were globular (14.2%), flattened (19.0%); oblate (33.3%), elliptical (2.38%), pyriform (2.38%), elongated (23.8%) fruit shapes were identified (Fig.02). Variation was also found in predominant and secondary fruit skin colour, primary and secondary colour of immature fruit, secondary skin colour pattern. The maximum 47.6% light yellow fruit colour was dominating within the collection. Vijayalatha, (2022) also observed oval and round shape fruit and yellow and orange type fruit color. The highest variation was observed in colour of fruit skin by Malek *et al.* (2012). Among the forty-two germplasm, the maximum twenty (20) germplasm showed a dark green type primary colour of immature fruit. All germplasm showed very short fruit skin hairiness. (Table 03).

In the collected germplasm 14.2% germplasm showed obtuse shape of fruit ribs, 11.9% intermediate, and 50.0% acute among the germplasm. Malek *et al.* (2012) also found no fruit ribs in four germplasm, superficial ribs in twenty-seven germplasm, and deep fruit ribs in thirty-six germplasm. In stem end shape, depressed, flattened, rounded, and pointed shapes were observed (Table 3). Different characters related to fruits were also recorded by Choudhary *et al.* (2015). Among the germplasm, a wide variation of fruit color and shape showed the morphological diversity of muskmelon in Bangladesh.

Fruit non-cracking habit of muskmelon is an important trait for marketing. It is challenging to transport from one place to another due to the splitting nature of fruit (Malek *et al.* 2012). In fruit cracking habit, 28.5% germplasm showed deep cracking, 9.5% intermediate, and 33.3% superficial. Malek *et al.*, (2012) also found three types of fruit cracking habit among them two germplasm had no cracking habit. Pale orange flesh color was recorded for 22 germplasm (52.38%), cream color for 12 accessions (28.5%), and orange, white, and yellow for 4, 2, and 2 germplasm, respectively. Three types of flesh color such as white for twenty-five germplasm, yellow for three germplasm, and orange for thirty-nine germplasm were also observed among the

Table 2: Qualitative variation of stem, leaf, and flower characters in muskmelon germplasm

Descriptor	Descriptor state	Number of germplasm	Percent (%) of germplasm
Stem colour	Green	14	33.3
	Dark green	28	66.6
Leaf outline	Broadly ovate	42	100
Leaf shape	Entire	34	80.9
	Trilobate	7	16.6
	Penta lobate	1	2.3
Leaf lobe	Shallow	37	88.1
	Intermediate	4	9.5
	Deep	1	2.3
Leaf margin dentation	Weak	27	64.2
	Intermediate	6	14.2
	Strong	9	21.4
Leaf pubescence density	Sparse	28	66.6
	Intermediate	8	19.0
	Dense	6	14.2
Leaf pubescence type	Intermediate	22	52.3
	Hard	20	47.6
Leaf colour	Dark green	12	28.5
	Green	30	71.0
Leaf glossiness	Glossy	16	38.1
	Intermediate	15	35.7
	Dull	11	26.1
Prominent leaf vein	Present	42	100
Flower color	Yellow	42	100

Figure 2: Globular (14.29%), flattened (19.05%); oblate (33.33%), elliptical (2.38%), pyriform (2.38%), elongated (23.81%) fruit shapes were identified in muskmelon.

studied germplasm by Malek *et al.* (2012). Germplasm showed a grainy-firm fruit flesh texture was 69.0% and all germplasm contained internal aroma (Table 04).

Quantitative Character

Substantial variation was noticed concerning flowering, fruit size, and fruit weight (Table 05) Maximum coefficient of variation of 73.5 % was estimated in fruit weight followed by fruit length (46.35%). Madhumathi

Table 3: Qualitative variation of fruit characters in muskmelon germplasm.

Descriptor	Descriptor state	Number of germplasm	Percent (%) of germplasm
Fruit shape	Globular	6	14.2
	Flattened	8	19.0
	Oblate	14	33.3
	Elliptical	1	2.3
	Pyriform	1	2.3
	Ovate	2	4.7
	Elongated	10	23.8
Predominant fruit skin colour	Light yellow	20	47.6
	Cream	1	2.3
	Pale green	4	9.5
	Green	12	28.5
	Orange	5	11.9
Secondary fruit skin colour	Light yellow	10	23.8
	Pale green	16	38.1
	Green	14	33.3
	Orange	2	4.7
The primary colour of immature fruit	Light green	11	26.1
	Intermediate	11	26.1
	Dark green	20	47.6
The secondary colour of immature fruit	Light green	13	30.9
	Intermediate	14	33.3
	Dark green	14	33.3
	Cream	1	2.3

Table 4: Qualitative variation of external and internal fruit characters in muskmelon germplasm.

Descriptor	Descriptor state	Number of accessions	Percent (%) of accession
Fruit cracking habit	Absent	12	28.5
	Superficial	14	33.3
	Intermediate	4	9.5
	Deep	12	28.5
Flesh colour	White	2	4.7
	Yellow	2	4.7
	Cream	12	28.5
	Pale orange	22	52.3
	Orange	4	9.5
Flesh texture	Smooth-firm	13	30.9
	Grainy-firm	29	69.0
Flesh favour	Insipid	27	64.2
	Intermediate	15	35.7
Placenta colour	Yellow	11	26.1
	Orange	31	73.8
External aroma	Absent	12	28.5
	Present	30	71.4
Internal Aroma	Present	42	100

et al. (2020) also found that the highest CV in the case of length of fruit (23.69%) which was followed by thickness of pulp (17.07%), fruit girth (16.84%), number of seeds per fruit (12.08%) and weight of fruit (7.43%). Characters that showed a wide range of variation would be given preference for selection (Malek *et al.*, 2012). The minimum CV was observed in days to 50% flowering (12.48%). On average, days to 1st flowering were 50 days, and days to 50% flowering were 59 days. The earliest germplasm was IAH-345

Table 5: Quantitative listing data and descriptive analysis.

	Collector's number	Days to 1st flowering	Days to 50% flowering	Fruit length (cm)	Fruit width (cm)	Flesh thickness (mm)	Fruit weight (kg)
1	AC-27	52.0	61.0	20.6	9.5	3.4	1.2
2	AC-86	49.0	52.0	20.0	13.3	2.5	2.2
3	AC-140	51.0	60.0	14.0	15.0	2.8	1.3
4	AC-208	78.0	88.0	23.5	12.5	2.5	1.2
5	AC-237	49.0	59.0	22.5	9.4	1.8	1.0
6	AC-303	52.0	62.0	20.3	17.8	3.0	3.3
7	AC-386	51.0	61.0	17.0	15.0	2.0	1.5
8	AC-387	53.0	63.0	19.0	18.0	2.8	1.9
9	AC-388	52.0	62.0	11.0	12.7	2.5	1.0
10	AC-391	49.0	58.0	9.5	11.5	1.3	0.6
11	AC-408	50.0	62.0	21.3	15.5	2.6	1.8
12	AC-422	33.0	43.0	10.0	14.0	3.0	1.0
13	AHM-15	50.0	60.0	11.0	5.0	1.0	0.3
14	AMA-39	50.0	60.0	23.2	12.6	2.1	1.4
15	IAH-14	52.0	62.0	11.2	10.4	2.5	1.0
16	IAH-69	44.0	52.0	15.5	12.0	2.3	0.9
17	IAH-187	49.0	58.0	14.3	12.5	2.0	1.0
18	IAH-194	51.0	60.0	51.0	14.0	3.0	5.3
19	IAH-197	59.0	69.0	13.0	10.0	2.0	0.7
20	IAH-198	51.0	61.0	11.8	8.5	1.0	0.5
21	IAH-199	49.0	58.0	32.0	13.0	2.0	2.6
22	IAH-207	50.0	59.0	43.0	18.0	3.5	5.5
23	IAH-220	49.0	58.0	20.5	10.9	1.7	1.0
24	IAH-245	51.0	61.0	22.0	17.0	3.0	1.5
25	IAH-257	51.0	61.0	19.0	16.0	3.2	1.9
26	IAH-317	52.0	62.0	14.2	12.3	2.1	1.1
27	IAH-334	52.0	62.0	28.5	11.0	2.8	1.7
28	IAH-345	28.0	39.0	11.7	13.7	2.7	0.9
29	IAH-350	50.0	60.0	13.0	8.5	1.5	1.2
30	RAI-73	44.0	52.0	23.0	13.0	2.0	1.2
31	RAI-79	53.0	64.0	28.3	12.8	2.0	2.4
32	RAI-239	33.0	43.0	19.0	11.3	1.6	1.2
33	RAI-240	53.0	62.0	5.0	12.0	1.5	0.4
34	RC-186	54.0	63.0	40.3	14.2	3.0	4.5
35	TRMR-34	48.0	59.0	22.0	12.0	3.0	1.3
36	TRMR-36	54.0	63.0	13.3	10.2	2.3	0.7
37	TRMR-41	52.0	61.0	19.5	12.5	3.3	1.5
38	TRMR-69	50.0	60.0	23.3	12.3	1.5	1.7
39	TRMR-81	55.0	64.0	22.4	14.5	3.1	2.6
40	TRMR-83	48.0	57.0	16.5	12.5	3.1	1.0
41	TRMR-149	49.0	58.0	14.5	9.5	1.4	0.4
42	TRMR-160	78.0	88.0	51.0	18.3	1.3	5.5
	Minimum	28.0	39.0	5.0	8.5	1.0	0.3
	Mean	49.5	59.3	20.7	12.6	2.4	1.6
	SD	7.9	7.4	46.4	21.5	28.3	73.5
	CV%	14.5	12.5	46.4	21.5	28.3	73.5

(28 days) for days to 1st flowering followed by AC-422 (33 days). Fruit length range was 9.50 cm to 51 cm and width was 5 cm to 18 cm. The longest fruit length was recorded in germplasm IAH-194 (51 cm) whereas the shortest germplasm was AC-391 (9.50 cm). The average value of flesh thickness was 2.38 cm. The minimum fruit weight was 0.33 kg (AHM-15) and the maximum was 5.46 kg (IAH-207) (Table 05). Malek *et al.* (2012) also recorded the length of fruit (12.60-50.32 cm), breadth of fruit (23.20-52.00 cm), and weight of fruit (1.40-6.25 kg) among sixty-seven (67) germplasm. The studies of Pandey *et al.*, (2005), Pandey *et al.* (2009), and Choudhary *et al.* (2012) also narrated the diversity in Cucumis species in respect of different morphological, yield contributing characteristics along with yield. Characterization of germplasm concerning valuable traits will be assisted in the estimation of genetic diversity (Choudhary *et al.* 2015).

Germplasm Distribution and Dendrogram

Cluster analysis is a tool for assorting the materials into groups. Multiple variables are a trustworthy approach to dictate the similarities and differences of multiple numbers of germplasm by grouping (White *et al.*, 2012). The dimension of variation that would apply to future crop improvement programs is indicated by cluster analysis (Sultana *et al.*, 2006). Several authors have used this tool to represent their intraspecific relationship by morphological characterization (Arif *et al.*, 2013; Boampong *et al.*, 2018; Khadivi, 2018; Sabaghnia *et al*. 2014).

Multivariate analysis following Mahalanobis D^2 statistics (Mahalonobis,1936) displayed more genetic divergence for growth, earliness and traits that are associated with yield offering a proficient opportunity for development of muskmelon germplasm (Singh and Lal, 2000a; More and Seshadri, 2002; Choudhary and Ram, 2003; Krishnaprasad *et al*., 2004; Singh and Dhillon, 2006). Based on Mahalanobis's D2 values, five clusters were configured from forty-two accessions. (Table 06). The dendrogram (Fig. 03. displayed that the twenty-two germplasm were assembled into cluster III which was the maximum indicating overall genetic similarity among them, followed by thirteen germplasm in cluster V. Cluster I and II composed of only 3 of each, respectively. Singh and Lal (2000b); Rahman *et al.*, (2016) and Vijayalatha (2022) studied 51, 64, and 24 diverse muskmelon germplasm, respectively, and categorized them into 13, 5, and 10 clusters, respectively. Ninety-eight muskmelon germplasm evaluated by More and Seshadri (2002) was obtained from ten countries and this 98 germplasm was grouped into twelve clusters.

Cluster Means

The genetic differences between clusters were reflected by cluster means. Six characters' mean values studied in musk melon germplasm for five clusters are shown in Table 07. clusters were distinguished from each other for all studied traits. Cluster IV displayed the maximum mean value for days to first and fifty percent flowering and the minimum mean value was found for these two characters in Cluster II. So, the germplasm belonging to cluster II will give early fruiting. Cluster I also displayed the highest values for fruit length and width (cm), and flesh thickness (cm). Rahman *et al.* (2016) also found the maximum mean value for fruit length in cluster VI among the six divided clusters. So, the germplasm in cluster I being distinct from other clusters may tend to prospective parents for future breeding programs. Germplasm in cluster I had the highest cluster mean value for individual fruit weight (kg). Tomar *et al.* (2008) also observed that among the seven clusters, cluster III had the highest mean value for fruit length, fruit weight, and flesh thickness. This useful finding indicates their individualistic resemblance and significance due to traits possessed by them (Reddy *et al.*, 2017). Through clusters it will be easy to get which specific germplasm with traits of interest will help in researching more germplasm with related traits in crop improvement programs (Naghavi and Jahansouz, 2005) and grouping of germplasm into different clusters gives a chance to select germplasm for development of high yielding as well as good quality varieties. Extensive information on the type and consequence of genetic divergence of germplasm is the precondition of a variety improvement program.

Principal Component Analysis (PCA)

Principal Component Analysis (PCA) is a trustworthy multivariate approach that transforms a huge number of data sets in the form of a limited component that comprises many inter-correlated variables (Pachauri *et al.*, 2017). The investigation was carried out to find out the prime distinguishing characters that cause variation among forty-two muskmelon germplasm by calculating the first two principal components which accounted for 75.70 % of the total divergence (Fig. 04). The musk melon germplasm RC-186, IAH-194, IAH-207, AHM-15, IAH-197, IAH-345, AC-422 and RAI-239 were separately isolated from the others and they were away from centroid. This result displayed the uniqueness and divergence of the germplasm. In general, all the data were lessened to five principal components (PC) or factors that represent the total variability. The first

Table 6: Distribution of forty-two germplasm in five different clusters based on quantitative characters

Cluster	Number of germplasm	Germplasm included in different clusters
I	3	IAH-194, IAH-207, RC-186
II	3	AC-422, IAH-345, RAI-239
III	22	AC-27, AC-86, AC-140, AC-303, AC-386, AC-387, AC-388, AC-408, IAH-14, IAH-69, IAH-18,7 IAH-245, IAH-257, IAH-317, IAH-334,
IV	1	AC-208
V	13	AC-237, AC-391, AHM-15, AMA-39, IAH-197, IAH-198, IAH-199, IAH-220, IAH-350, RAI-79, RAI-240, TRMR-69, TRMR-149

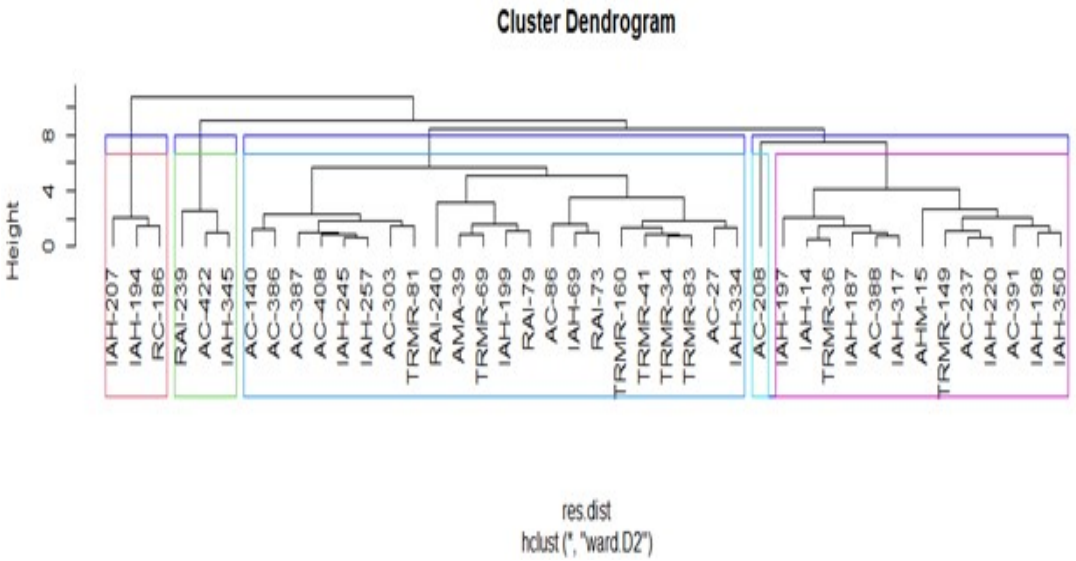

Figure 3: Cluster dendrogram depicting morphological diversity among muskmelon germplasm

Table 7: Cluster means six characters of forty-two muskmelon germplasm.

Characters	I	II	III	IV	V
Days to 1st flowering	51.67	31.33	50.41	78.00	50.85
Days to 50% flowering	60.67	41.67	59.50	88.00	60.54
Fruit length (cm)	44.78	13.55	18.30	23.50	20.59
Fruit width (cm)	15.39	13.00	13.36	12.50	10.46
Flesh thickness (cm)	3.17	2.42	2.70	2.50	1.64
Fruit weight (kg)	5.1	1.04	1.50	1.19	1.10

Table 8: Principal Components for six traits of muskmelon germplasm.

Characters	PC1	PC2	PC3	PC4	PC5	PC6
Days to 1st flowering	-0.2480	0.6482	-0.1258	0.0074	0.0295	0.7082
Days to 50% flowering	-0.2374	0.6522	-0.1342	-0.0679	0.0160	-0.7039
Fruit length (cm)	-0.4648	-0.0170	0.6521	0.1184	-0.5868	-0.0081
Fruit width (cm)	-0.4492	-0.2689	-0.3671	-0.7428	-0.1947	0.0395
Flesh thickness (cm)	-0.4172	-0.2324	-0.5639	0.6544	-0.1569	-0.0339
Fruit weight (kg)	-0.5388	-0.1669	0.2970	0.0369	0.7694	-0.0156
Eigen value	2.60	1.94	0.86	0.38	0.19	0.019
Variability (%)	43.29	32.41	14.34	6.41	3.25	0.31
Cumulative (%)	43.29	75.70	90.04	96.45	99.69	100

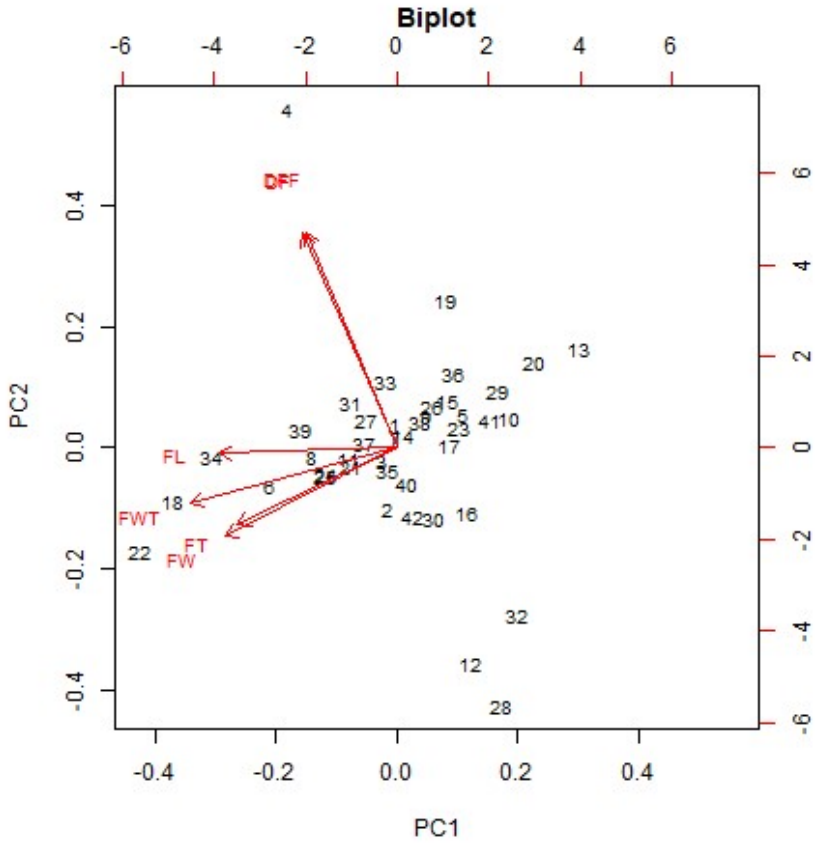

Figure 4: The plot of the first two PC 1 and PC 2 shows the relationship between germplasm and characters.(DF= days to 1st flowering; DFF= days to 50% flowering; FL=fruit length; FW=fruit width; FL= flesh thickness and FWT= fruit weight, PC=principal component)

principal component explained 43.29% of the total variation and the second one explained 32.41% of the variation in forty-two musk melon germplasm. Thus, the present study exposed that the first PC was more important than the second PC for explaining the variation among the germplasm based on studied traits. Usually, the first principal component imparted toward maximum divergence while other factors justify the rest amount of the variance (Fereidoonfar *et al.*, 2018). The eigen values and vectors of eight characters for a PCA of important traits for the first fifth principal components in forty-two musk melon germplasm were shown in Table 08. A related study was conducted by Henane *et al.* (2013) on muskmelon in Tunisia. Melon germplasm collected from different geographic regions of Tamil Nadu of India also reported high morphological variation (Vijayalatha, 2022).

CONCLUSION

All the newly collected muskmelon germplasm display variation for most of the studied qualitative characters. Multivariate analysis on quantitative characters revealed that Mahalanobis D^2 statistics grouped the germplasm into five clusters where cluster III had the maximum germplasm. Germplasm RC-186, IAH-194, and IAH-207 were selected for heavy fruit weight; IAH-345, AC-422, and RAI-239 for early fruiting. These findings indicated an immense range of diversity for studied traits which will contribute a valuable source of gene pool in the melon breeding program.

REFERENCES

Arif, M., Jatoi, S.A. and Rafique, T. (2013). Genetic divergence in indigenous spinach genetic resources for agronomic performance and implication of multivariate analyses for future selection criteria. Science Technology and Development (Pakistan). 32, 7–15.

Bello, O.B. and Olawuyi, O.J. (2015). Gene action, heterosis, correlation and regression estimates in developing

hybrid cultivars in maize. *Tropical Agriculture*, 92, 102–117.Retrieved from https://www.researchgate.net/publication/271195887.

Boampong, R., Aboagye, L.M. and Nyadanu, D. (2018). Agromorphological characterization of some taro *(Colocasia esculenta (L.) Schott.)* germplasms in Ghana. *Journal of Plant Breeding and Crop Science*, 10(8), 191–202. DOI:10.5897/JPBCS2018.0734.

Choudhary, B. R., Kumar, S. and Sharma, S. K. (2012). Genetic variability and inter-trait association in muskmelon *(Cucumis melo* L.)under arid conditions. *Crop Improvement Special Issue*, 473–477.

Choudhary, B. R., Pandey, S., Rao, E. S. and Sharma, S. K. (2015). DUS characterization of muskmelon *(Cucumis melo)* varieties. *Indian Journal of Agricultural Sciences*, 85 (12), 1597–1601. Retrieved from https://www.researchgate.net/publication/286933870.

Choudhary, H. and Ram, H.H. (2003). Genetic diversity studies in muskmelon. *Annals of Agricultural Research*.24(2), 345-349.

Dildar, S., Leskovar, D.I., Sharma, S.P., Sarao, N.K. and Vashisht, V.K. (2020). Genetic diversity and interrelationship among Indian and exotic melons based on fruit morphology, quality components, and microsatellite markers. *Physiology and Molecular Biology of Plants*, 26, 985–1002. DOI: https://doi.org/10.1007/s12298-020-00814-1.

Fereidoonfar, H., Salehi-Arjmand, H. and Khadivi, A. (2018). Morphological variability of sumac *(Rhus coriaria* L.) germplasm using multivariate analysis. *Industrial Crops and Products*, 120,162–170. DOI: https://doi.org/10.1016/j.indcrop.2018.04.034.

FRG, 2018.Fertilizer Recommendation Guide. Bangladesh Agricultural Research Council. Farmgate, Dhaka-1205.

Glaszmann, J.C., Kilian, B., Upadhyaya, H.D. and Varshney, R.K. (2010). Accessing genetic diversity for crop improvement. Current Opinion of Plant Biology, 13,167–173. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S1369526610000117..

Henane, I., Mezghani, N., Tlili,I., Thouraya, R., Ismail, G., Kamel, A. and Hager, J. (2013). Agro-morphological characterization and assessment of variability in local germplasm of *Cucumis melo in Tunisia. Journal of Biodiversity and Environmental Sciences*.3(12), 198-207. Retrieved from https://www.innspub.net/wp-content/uploads/2022/03/JBES-V3-No12-p198-207.pdf.

Janghel, A.K., Trivedi, J., Sharma, D., Lodhi, Y.K. and Kumar, L. (2018). Genetic variability in muskmelon *(Cucumis melo* L.) under protected conditions. *International Journal of Current Microbiology and Applied Science*. 6, 211-217. Retrieved from https://www.ijcmas.com/special/6/Arvind%20Kumar%20Janghel, %20et%20al.pdf.

FKhadivi, A. (2018). Phenotypic characterization of Elaeagnus angustifolia using multivariate analysis. *Industrial crops and products*. 120, 155–166. In:https://agris.fao.org/agris-search/search.do?recordID=US201900224907.

Krishnaprasad V.S.R., Pitchaimuthu, M., and Dutta, O.P. (2004). Variation, diversity pattern, and choice of parental selection in musk melon *(Cucumis melo* L.) improvement.*Indian Journal of Horticulture*. 61(4), 319-322.

Kurlovich, B.S. (1998). Species and intraspecific diversity of white, blue, and yellow lupins.*Plant Genetic Resources Newsletter*. 115, 23–32.

Madhumathi, D., Reddy, S. and Prasad, B.H.V. (2020). Genetic diversity in muskmelon *(Cucumis melo). Indian Council of Agricultural Research*. 90 (5), 934–937.

Mahalonobis, P.C. (1936). On the generalized distance in statistics. In: Proc. Nat. Acad. Sci. India. 2, 49-55

Malek, M. A., Islam, M.O., Haque, M.M. and Sultan, M. K. (2012). Screening of muskmelon *(Cucumis melo* L.) germplasm against salinity. *Bangladesh Journal of Agricultural Research*.37, 465-472. DOI:https://doi.org/10.3329/bjar.v37i3.12124.

Mercy G.A. and Bosa E.O. (2013). The morphological characterization of the melon species in the family cucurbitaceae juss., and their utilization in Nigeria. *International Journal of Modern Botany*. 3, 15-19. DOI: 10.5923/j.ijmb.20130302.01.

More, T. A. and Seshadri, V. S. (2002). Studies on genetic divergence in muskmelon *(Cucumis melo* L.). *Journal Maharastra Agricultural University*. 27, 127-131.

Naghavi, M.R. and Jahansouz, M.R. (2005). Variation in the agronomic and morphological traits of Iranian chickpea accessions. *Journal of Integrative Plant Biology*. 47, 375379.DOI: https://doi.org/10.1111/j.1744-7909.2005.00058.x

Pachauri, A.K., Sarawgi, A.K. and Bhandarkar, S. (2017). Agro-morphological characterization and morphological-based genetic diversity analysis of rice *(Oryza sativa* L.) germplasm. *Journal of Pharmacognosy and Phytochemistry*. 6, 75–80. Retrieved from https://www.phytojournal.com/archives/2017/vol6issue6/PartB/6-5-469-319.pdf.

Pandey, S., Kashya, S. K., Jha, A., Choudhary, B.R., Kumar, S., Singh, D.K. and Rai, M.(2009). Inter-trait association and genetic variability assessment in snapmelon *(Cucumis melo var. momordica). Indian journal Plant Genetic Resources*. 22(2), 113–116. Retrieved from https://agris.fao.org/agris-search/search.do?recordID=IN2022002397

Pandey, S., Rai, M. and Singh, B. (2005). Genetic variability and character association in muskmelon *(Cucumis melo* L.). *Indian Journal Plant Genetic Resources*.18 (2), 212–216.

Pitrat, M. (2008). Melon *(Cucumis melo* L.). In: Prohens J. Nuez F (eds), Handbook of crop breeding, Vegetable, Springer, New York. 1: 283-315. DOI: 10.1007/978-0-387-30443-4_9.

Rahman, S., Miah, M. A. K and Rahman, H. (2016). Genetic diversity of muskmelon using multivariate technique. *Bangladesh Journal Agriculture Research*. 41(2), 273-286. https://www.banglajol.info.

Reddy, B., Begum, H. Sunil, N and Reddy M. T. (2017). Genetic divergence analysis in muskmelon *(Cucumis melo* L.). *International Journal of Current Microbiology and Applied Sciences*.6, 2251–2260. DOI: https://doi.org/10.20546/ijcmas.2017.603.267.

Reddy, B.P.K., Begum, H., Sunil, N., Reddy, M.T., Babu, J.D., Reddy, R.S.K. and Reddy, B.P.(2012). Genetic divergence analysis in muskmelon *(Cucumis melo* L. *Asian Journal of Science and Technology*. 4(12), 1-6.https://www.journalajst.com/genetic-divergence-analysis-muskmelon-cucumis-melo-l.

Sabaghnia, N., Asadi-Gharneh, H.A. and Mohammadi, M. (2014). Genetic diversity of spinach *(Spinacia oleracea* L.) landraces collected in Iran using some morphological traits. *Acta agriculturae Slovenica*. 103(1), 101–111. DOI: 10.14720/aas.2014.103.1.11.

Sebastian, P., Schaefer, H., Telford, I.R.H. and Renner, S.S. (2010). Cucumber *(Cucumis sativus)* and melon *(Cucumis melo)* have numerous wild relatives in Asia and Australia, and the sister species of melon is from Australia. In: Proceedings of the National Academy of Sciences of the United States of America. 107. 14269-73.DOI: http://dx.doi.org/10.1073/pnas.1005338107.

Seshadri, P. and Ganesamurthy, K. (2002). Genetic divergence in soybean *(Glycine max L.). Madras Agriculture. Journal*. 89(1/3), 18-21.

Shivapriya, M., Mamatha, S., Umesha, K., Lingaiah, H.B. and Mohankumar, S. (2021). Genetic variation in melon *(Cucumis melo* L.) landraces and wild relatives of Karnataka state of southern India. *Plant Genetic Resources: Characterization and Utilization*. 19(5), 1-9. DOI: http://dx.doi.org/10.1017/S1479262121000496.

Singh G and Dhillon N.P.S. (2006). Genetic divergence in muskmelon germplasm. *Haryana Journal of Horticultural Sciences*. 35(3/4), 340-341.

Singh, S. and Lal, T. (2000a). Assessment of genetic divergence in melon *(Cucumis melo* L.). *Journal of Research, Punjab Agricultural University*. 37(1-2), 36-41.

Singh, S. and Lal, T. (2000b). Genetic divergence among five muskmelon cultivars. *Horticultura Brasileria*, 20, 171-173.

Srivastava, V., Mahajan, R.K., Gangopadhyay, K.K., Singh, M. and Dhillon, B.S. (2001). Minimal Descriptors of Agri Horticultural Crops. Part II: Vegetable Crops. PB Mission Leader National Agricultural Technology Project on Plant Biodiversity (NATPPB) and NBPGR, New Delhi. Monnto Publishing House, New Delhi.

STAR, version 2.0.1 (2014). Biometrics and Breeding Informatics, PBGB Division, International Rice Research Institute, Los Banos, Laguna.

Sultana, T., Ghafoor, A. and Ashraf, M. (2006). Geographic pattern of diversity of cultivated lentil germplasm collected from Pallistanas assessed by protein assays. *Acta Biologica Cracoviensia Series Botanica*. 48, 77–84

Sunita, P.K. and Hosakatte, N.M. (2013). Estimation of phenotypic divergence in a collection of *Cucumis melo* from Kerala State, Southern India. *Agricultural Science*. 4(7), 21-31. DOI: http://dx.doi.org/10.4236/as.2013.47A004.

Tomar, S. K., Kulkarni, G.U. and Kakade, D.K. (2008). Genetic analysis in muskmelon *(Cucumis melo* L.). Journal of Horticultural Science. 3(2), 112-118. In: https://www.academia.edu/2289061/.

Vijayalatha, K.R. (2022). Genetic divergence analysis in Muskmelon *(Cucumis melo* L.).*The Pharma Innovation Journal*. 11(2), 446-450.

White, J.W., Andrade-Sanchez, P. and Gore, M.A. (2012). Field-based phenomics for plant genetics research. *Field Crops Research*. 133, 101–112. DOI: https://doi.org/10.1016/j.fcr.2012.04.003

Yildiz, M., Akgul, N. and Sensoy, S. (2014). Morphological and molecular characterization of Turkish landraces of *Cucumis melo L. Notuale Botanicae Horti Agrobotanici Cluj-Napoca* 42(1), 51-55. In: https://www.notulaebotanicae.ro/index.php/nbha/article/view/9452.