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Research Article

Genetic Diversity of Cucumber Germplasm Collected and Conserved at the Plant Genetic Resources Centre of the Bangladesh Agricultural Research Institute

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Abstract

Over a period of three decades, from inception in 1987 to 2018, the Plant Genetic Resources Centre (PGRC) of the Bangladesh Agricultural Research Institute (BARI) collected and conserved about 11081 accessions of 89 crops in its gene bank. Cucumber germplasm accounts for 241 of these accessions. The genetic diversity of 33 cucumber germplasm that included 27 newly collected and 06 genebank accessions was assessed based on morphological traits in a study conducted in the research field of PGRC, BARI, Gazipur, during March-July 2017. Genebank accessions having viability below 85% and/or seed stock below the required amount were selected for the study. Eleven qualitative and ten quantitative traits were characterized. We used the Pearson's chi-squared (x^2) test to study the distribution of traits and the Shannon Weaver Diversity Index (H´) to measure the extent of variability of each trait. The distribution of traits showed that the germplasm was dominated by an oblong fruit shape with spiny skin texture, light green fruit skin at table maturity and brown fruit skin at physiological maturity. The CV values of fruit length (35.72%), fruit weight (18.33%), number of fruit/plant (31.93%) and individual fruit weight (35.14%) represented a preponderance of high variation of the characters. High diversities were noticed for all the four fruit traits (H´= 0.75-0.87). H´ values validated the results of the x^2 test and percent CV. Weaker diversity indices (0.21) were obtained in traits days to male initiation as well as pistillate flowers initiation of germplasm collected from Dhaka. Findings of this study revealed that the cucumber germplasm from Khagrachari and Jashore are potential candidates for improvement in fruit weight while that from Gazipur are marked by earliness and bearing habit.

Keywords: *Cucumis sativus*; Diversity Index; Morphological Traits; Coefficient of Variation; Monoecious

Introduction

Cucumber (*Cucumis sativus* L.), commonly known as "shosha" in Bengali, belongs to the family C*ucurbitaceae* [16,33]. It is a traditional vegetable of Bangladesh with great nutritional, medicinal and economic potential. It is open pollinated, propagated by seeds, the same plant bears male and female flowers that favors cross pollination and allows for greater genetic diversity (GD). Since the beginning of systematic plant breeding, natural variability and divergence among crops have been extensively studied and used in the improvement of crop species. In the context of global climate change and associated unforeseen events it may serve as the reservoir of many novel traits conferring tolerance to different biotic and abiotic stresses. Diversity in plant is shaped more strongly in space and time by climate variables across the geographic gradient through the adaptation processes [42]. However, with the progress of time, natural variability of cucumber in Bangladesh plummeted due to lopsided breeding practices focusing on improvement of yield and its component traits, frequent use of a few selected genotypes as parents in varietal development programs and introduction of a few outstanding lines in many countries resulting in an increased genetic similarity among modern crop cultivars.

The plant Genetic Resource Centre (PGRC) of the Bangladesh Agricultural Research Institute (BARI) has been engaged in the collection and conservation of diverse crop germplasm including that of cucumber for future crop improvement programs. At present, PGRC has more than 11081 accessions of 38 crops including 241 of cucumber [2]. During the germplasm collection season of 2017-18, PGRC collected 139 more cucumber germplasm and worked for their characterization and field evaluation [20]. Conservation of genetic diversity in a plant genetic resources (PGR) program provides tools for monitoring population and conservation planning. The

most important component of PGR is characterization of the accessions and generation of information on traits for facilitating their maximum utilization in varietal development agenda. Plant characterization by morphological, physiological and agronomic traits has long been used in selective breeding. Moreover, this technique is relatively easy, cost effective and requires less time and minimum technical knowledge. Morphological diversity of ecotypes signifies variability of responses to environmental stresses. The present study, therefore, was undertaken for characterizing selected germplasm morphologically and estimating their genetic diversity.

Methods

Selecting germplasm

We conducted the field trial at the central research station of the PGRC, BARI, Gazipur, during March -July 2017. Considering availability of field space, labor, inputs and technical manpower of PGRC, 33 germplasm consisting of 6 accessions of the gene bank and 27 newly collected germplasm were strategically selected and included in the trial. In doing so, priority was given to accessions having viability below 85% and/or amount of seed stock below the optimum level.

Geographic locations of germplasm collection

We adopted a coursed grid sampling strategy to determine the geographic locations of germplasm belonging to each district. Each quadrate of a 40 square km grid box (20 x 20 km) was marked on the map by latitudinal and longitudinal directions. Each division (quadrate) along the longitude direction was marked in alphabetic order (A, B, C etc.) while the latitude divisions were marked numerically starting with 1. All grids representing the germplasm sources were identified and the number of entries in each grid was recorded as well. We used GIS tools to delineate the district boundaries. Each accession was identified with an Accession no., Grid no. and Sample no. (Figure 1). According to an earlier report, socioeconomic conditions, land use patterns and environment within a grid box were relatively uniform [29]. Differences in rainfall, temperature, soil pH, environmental CO_2 between any two-grid box increased with an increase in their geographic distance from each other [39].

Experimental design

It was a non-replicated experiment without any statistical design. The unit plot size was 3m x 3m maintaining a 0.5m drain between the plots. Germplasm was assigned randomly to the different plots. One accession with three plants represented a treatment. Seeds were sown in polybags on 2 March 2017 and seedlings were transplanted in the main filed on 10 April 2017. Weeding, irrigation and spraying of insecticides were done as and when needed throughout the cropping season to ensure proper plant growth and development.

Harvesting and data recording

We harvested fruits at physiological maturity. Data on plant growth habit, stem color, leaf intensity of green color, stem pubescence, leaf length and width, fruit number per plant, weight of fruits per plant, fruit length, fruit width, shape of fruit and fruit skin color at table maturity and physiological maturity were recorded following standard descriptors [9].

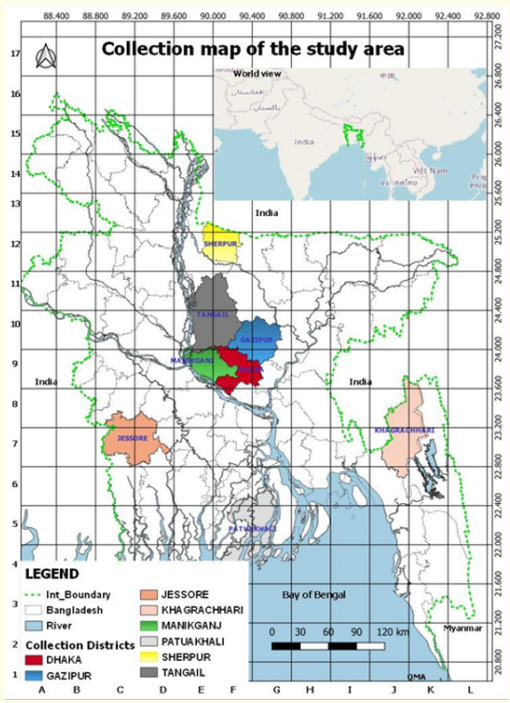


Figure 1: Locations of sample populations of Cucumis sativus L on a grid map of Bangladesh (population codes correspond to those given in Table 1 and Table2.

Statistical analysis

We used the chi-squared (χ^2) test and compared the observed and the expected frequencies for each character. To calculate the expected frequencies for a uniform distribution, the total of the observed frequencies was divided by the number of categories. The critical value (χ^2_c) at 95% level of significance was determined on the basis of the degree of freedom (df) and inference was made under the following decision: Reject H_0 if $\chi^2 * > \chi^2_c$ ($\chi^2 *$ is the calculated value, df = k-1 where k is the number of categories).

The diversity index of Shannon-Weaver (1949) as described by Jain., *et al.* (1995) was used for estimating diversity of each morphological character of the germplasm [15,35]. The pooled H′ was computed and used for comparing the overall performance of germplasm in each group. H′ (in a 0 to 1 scale where 1 indicates the maximum diversity) is defined as

$H' = -\Sigma P_i \log_2 P_i$ where

P_i is the proportion of the total number of genotypes belonging to the i^{th} class. The exact descriptor defines the classes for the qualitative characters. For the quantitative characters, the overall genotypes mean ($\bar{X}$) and standard deviation (σ) were used to subdivide the population values (x_i) into 10 frequency classes

ranging from class 1 (if $x_i \leq -2\sigma$) to class 10 (if $x_i \leq \overline{X} +2\sigma$), the class interval being 0.5σ. The relative frequencies for the different classes were used to calculate the diversity index. The H′ for each character was calculated using MS Excel [35]. Test statistic H_0: H′/= 0 H′/is classified as high when H′ ≥ 0.66, moderate when H′=0.34-0.66 and low variation when H′ < 0.33 [36].

Results and Discussion

Cucumber germplasm conservation at PGRC-BARI

Data in table 1 and locations of sample population (Figure 1) imply that cucumber germplasm at the PGRC, BARI belong to 25 districts. It also implies that the samples are highly concentrated in Chattogram, Mymensingh, Gazipur and Khagrachari districts. The future collection strategy should, therefore, include areas from where collection of germplasm in adequate numbers has not yet been done.

Grid boxes

Figure1 visualizes the grid boxes (40^2 km), a 20 x 20 km size quadrate from where germplasm was collected. Overlaying of the grid boxes on an administrative map of Bangladesh demarcated the germplasm and districts of collection. Hypothetically, the grid boxes ensured environmental homogeneity which was also expected in districts of nearby grids. For example, Dhaka, Gazipur, Manikganj and Tangail are neighboring districts. Dhaka and Manikganj are adjacent to each other and represent an ecosystem with environmental homogeneity. Ecological and sociological similarities between the bordering areas of neighboring districts are not distinct. Large geographical distances on the other hand among Jashore, Jamalpur, Khagrachari, Sherpur and Patuakhali resulted in differences regarding social and environmental variables. It means that geographic distance is an important driver of adaptive divergence process [40]. Contrasting ecological conditions of collection sites have a strong influence in shaping genetic variations [39,40]. The geographic extent of Khagrachari district along the latitudinal direction (grid boxes J6-J8, K6-K9) reduced environmental homogeneity and increased genetic diversities of germplasm [10,13,38].

Distribution of qualitatively measured leaf and stem characters

The monoecious annual prostrate creeping vine of long main stem exhibited an indeterminate growth habit, leaves and stem were pubescent having tendril, which could coil around a support. Accessions producing light green leaves were maximum I number and dominated over medium green accessions (Table 2,3). Two distinct vine colors viz, (1) light green and (2) dark green were observed in the samples and light green was found dominating over dark green vine. Variation of shades in green color of stem might be a mechanism of photoprotection and other responses of plants to strong light stress [7]. Photosynthesis mainly occurs in the leaves of plant due to the presence of green pigment called chlorophylls. Because of varying ratios of chlorophyll as well as the presence of other pigments such as xanthophyll and carotenoid, the leaves exhibit many shades of green (light green/dark green) depending on their adaptation to climate and available light [1].

Sl. No	District	Geographic location (Grid)	Germplasm collected.(No.)
1	Manikganj	F9-10	7
2	Munshiganj	G8-9	4
3	Jhalokathi	F5-6, G5-6	3
4	Dinajpur	B14-15, C14-15, D14	4
5	Panchagarh	B16, C16	2
6	Bogra	D12-13, E12-13	1
7	Gazipur	G10-11	27
8	Rangpur	D14-15, C15	8
9	Thakurgaon	A15-16, B15-16	9
10	Dhaka	F9-10, G9-10	12
11	Narsingdi	H10-11	13
12	Khagrachari	K6-10	21
13	Jashore	C7-8, D7-8	14
14	Jhenaidah	C8-9, D8-9	16
15	Tangail	E10-11, F10-12	8
16	Narayanganj	G9, H9	11
17	Cumilla	I8-9, H9	6
18	Chattogram	J6-7, K4-7	32
19	Kurigram	E14-16	1
20	Chandpur	H8	3
21	Jamalpur	E12-14, F12	5
22	Mymensingh	G11-13, F12, H12,	29
23	Rangamati	K6-9, L6-9, M5-6	1
24	Sherpur	F13	2
25	Patuakhali	G5-6	2
			n = 241

Table 1: Cucumber germplasm holdings in the PGRC, BARI.

Distribution of qualitatively measured fruit character

Fruit shape

In cucumber-descriptor four (04) shapes of fruits are stated [9]. At petiole attachment (stalk end), fruit shapes are (1) obtuse (2) acute while at blossom end fruit shapes are (1) flat and (2) tapered (Table 4 and Figure 3). The distribution of accessions under each category was independent. Obtuse shaped fruit at petiole attachment was dominated over acute shaped while flat shaped fruits in blossom end was dominated over tapered shaped. Based on whole fruit-shape, the genotypes could again be grouped in three categories viz. oblong, ovate (Figure 3). Genotypes producing oblong fruits found dominating over oval and ovate shapes (Table 4).

Fruit skin color at table maturity

Two skin textures viz. (i) spiny and (ii) smooth skins found in the collection which was distributed independently and spiny fruits dominating over germplasm producing smooth skinned fruit. In the collection, five skin colors at table maturity namely (i)

Sl. No.	District of collected	Location on grid map	Germplasm	No. of entries
1	Dhaka	G9, G10, F9, F10	AC-304, AH-54, AH-59, AH-60, AH-61,	5
2	Gazipur	G10, G11	BD-4241, BD-4260, BD-4321, IAH-117, IAh-126, AC-356, AH-63, AH-66, BD10954, BD-9764	10
3	Jashore	D7, D8, E7	AHI-35, AHI-70, AHI-83, AHI-94	4
4	Khagrachhari	J7, J8, K6, K7, K8. K9	IAH-273, IAH-274, IAH-275, IAH-297, IAH-299, IAH-323, IAH-327, IAh-331	8
5	Manikganj	F9, F10	AC-207, AC-245	2
6	Sherpur	F12, F13	AMA-406	1
7	Tangail	F10, F11, F12	AC-74, AC-100	2
8	Patuakhali	G5	BD-10104	1
				n = 33

Table 2: Districts and geographical locations of cucumber germplasm under the trial.

Characters	Description	Observed Phenotype (n = 33)	Expected number	Value of χ^2	Level of significant
Type				-	
	Monoecism	33 (100)	-		-
	Dioeciously	0			
Growth type				-	
	Indeterminate	33	-		-
	Determinate	0			
Tendril					
	Present	33	-	-	-
	Absent	0			
Stem color					
	Light green	25 (76)	16.5	8.76	**
	Dark green	8 (24)	16.5		
Leaf intensity of green color					
	Light green	24 (73)	16.5	6.82	**
	Medium green	9 (27)	16.5		
Stem pubescence density					
	Absent	0			
	Medium	33 (100)	-	-	-
	Dense	0			
Leaf pubescence density					
	Absent	0			
	Medium	33 (100)	-	-	-
	Dense	0			

Table 3: Distribution of qualitatively measured plant characters.

Descriptor	Observed Phenotype	Number of genotype (n = 33)		Value of χ^2	Level of significant
		Observed	Expected		
Stem end fruit shape					
	Obtuse	28 (85)	16.5	16.03	**
	Acute	5 (15)	16.5		
Blossom end fruit shape					
	Flat	32 (97)	16.5	29.12	**
	Deep raised (Deep raised	1 (3)	16.5		
Whole fruit shape					

	Oblong	23 (70)	11	19.64	**
	Oval	5 (15)	11		
	Ovate	5 (15)	11		
Fruit skin texture					
	Spiny	27 (82)	16.5	13.36	**
	Smooth	6 (18)	16.5		
Fruit skin color at table maturity					
	Light green	19 (58)	6.6	33.21	*
	Green	7 (21)	6.6		
	Yellowish green	1 (3)	6.6		
	Blackish green	5 (15)	6.6		
	Whitish green	1 (3)	6.6		
Fruit skin color at maturity					
	Brown	25 (76)	16.5	8.76	**
	Yellow	8 (24)	16.5		

Table 4: Qualitatively measured fruit traits.

light green (ii) green (iii) yellowish green (iv)blackish and (v) whitish green were recognized. Distribution of accession under fruit colors at table maturity was independents. Among the five colors light green fruits at table maturity were found to dominate over other colors (Table 4).

Fruit skin color at maturity

In cucumber, descriptor [8] two skin colors of fruit at maturity viz. brown and yellow described. At physiological maturity, two skin colors viz. brown and yellow colors recorded in the collection (Table 4). Distribution of accessions under two (02) fruit colors at physiological maturity found independents and brown color genotype found to dominate over yellow color. As cucumber becomes botanically mature the chlorophyll in the skin fades and cucumber turns yellow or brown.

Descriptive statistics

Fruit length, fruit width, individual fruit weight, number of fruits/plant, yield and days to harvest (earliness) are some of the most important traits of cucumber and which display tremendous variation [25]. Their descriptive statistics including range, mean, standard deviation (SD) and coefficient of variation (CV) are summarized in table 5. The CV is a relative measure of variability that indicates the size of a standard deviation in relation to its mean. It is generally expressed as a percentage. The higher the CV, the greater the level of dispersion around the mean [5]. The estimated CV (35.72%) was the highest in fruit length. The CV of fruit weight and number of fruits/plant were closed to that of fruit length. Higher CV (18.33%) was also observed in fruit width. The CV of days to harvest was the smallest of all the traits analyzed. Thus, large variations were observed in fruit attributes of cucumber germplasm.

Figure 2(a) shows the distribution of fruit length among the genotypes. Fruit length ranged from 9 to 12 cm comprising 22 (66.67%) genotypes. Over 21% of the genotypes had fruit length higher between 17 to 22 cm. The distributions of fruit width among the genotypes illustrated in figure 2(b). Fruit width of most of the germplasm lies in the interval 5.50 to 6.75 cm and there are values in the data set that are much higher than the mean value of 5.25. Figure 2 (c) shows the distribution of germplasm on number of fruits/plant. In total, 24 germplasm (72.72%) had number of fruit between 4 to 6, there are values in the data set that are much higher than the mean value of 5.22 (8 to 10 fruits/plant). The distributions of individual fruit weight of the genotypes are illustrated in figure 2(d). Fruit weight of most of the germplasm lies in the interval between 260 to 353g, there are values in the data set that are notably different from other data points and much higher than the mean.

Character	Range	Mean	Standard deviation (Sx̆)	CV%
Internodes length (cm)	2.62-10.65	6.95	1.88	27.08
Leaf length (cm)	16.86-7.39	12.46	2.21	17.72
Leaf width (cm)	19.66-8.29	15.47	2.52	16.27
Days to staminate flower	42-36	37.62	2.24	5.95
Days to pistilate flower	43-52	46.65	3.47	7.44
Fruit length (cm)	4.6-21.76	11.52	4.12	35.72
Fruit width (cm)	3.7-8.08	5.16	0.95	18.33
No. of fruits/plant	3-8.5	5.27	1.69	31.93
Days to harvest	89-80	84.75	2.65	3.13
Fruit weight (g)	570-85	251.68	88.43	35.14

Table 5: Descriptive statistics of morphological characters.

Diversity indices of morphological traits

Diversity indices of Manikganj, Sherpur, Tangail and Patuakhali could not be estimated because of insufficient sample size. Comparison of diversity indices (H`) between Dhaka, Gazipur, Jashore and Khagrachari districts showed the presence of variabilities in

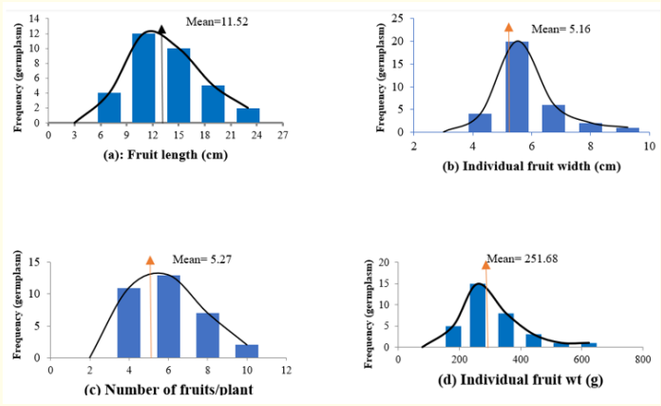


Figure 2: Distribution of fruit traits among the germplasm (a) fruit length (b) fruit width (c) number of fruits/plant and (d) individual fruit weight.

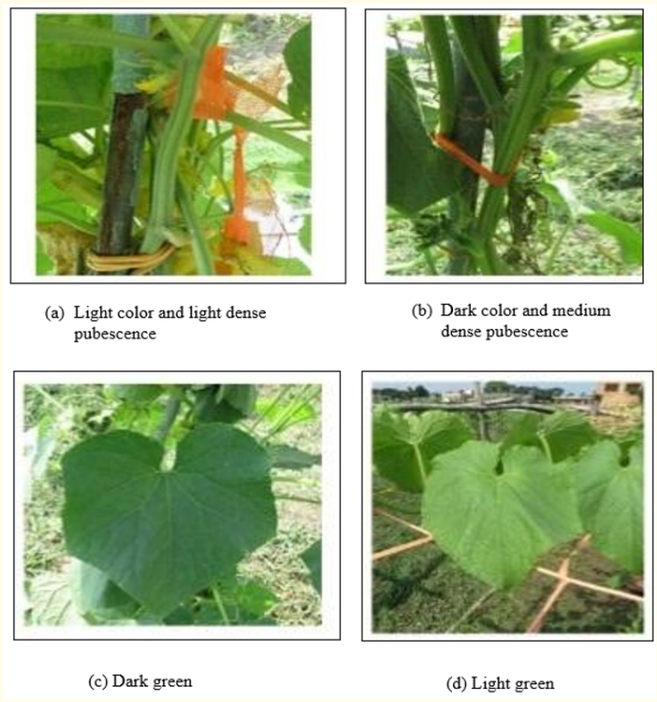
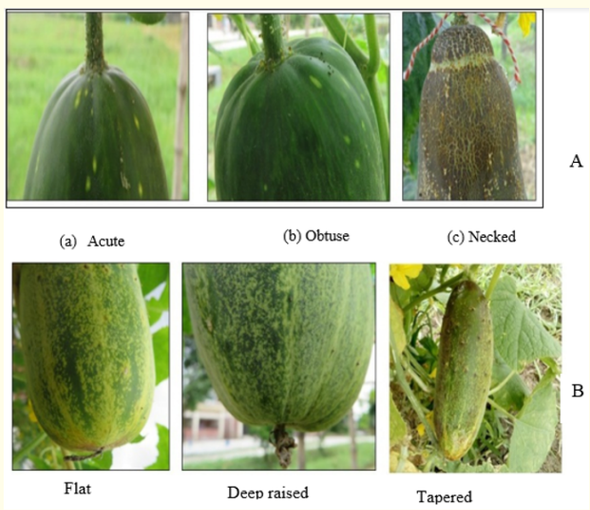


Figure 3: Green color intensity of stem (a and b) and leaf (c and d).



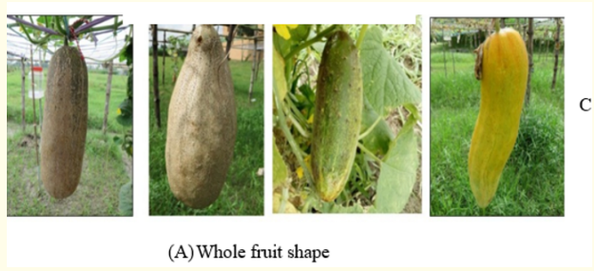


Figure 4: Fruit shape of cucumber germplasm (A) stalk end (B) Blossome end (C) Whole fruit.

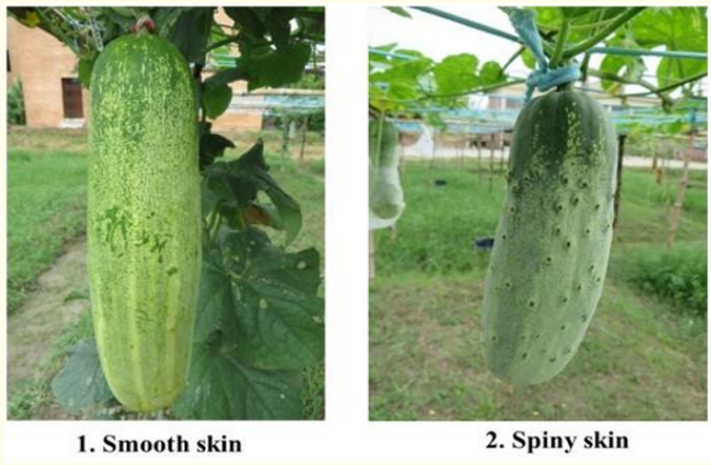


Figure 5: Skin texture of cucumber selected for the trial.

Figure 6: Fruit skin color at table maturity of cucumber selected for the trial.

Figure 7: Fruit skin color at physiological maturity of cucumber.

internode length, leaf size (leaf length x leaf width), fruit length, fruit weight, number of fruit per plant and individual fruit weight. The average diversity index of quantitative traits, 0.43, estimated for Dhaka was the lowest and the maximum diversity index of 0.57 was for Khagrachari followed by 0.51 for in Gazipur and 0.39 for Jashore (Table 6).

Location	Internode length (cm)	Leaf length (cm)	Leaf width (cm)	Days to staminate flower	Days to pistilat flower	Fruit length (cm)	Fruit width (cm)	No. of fruit/ plant	Days to harvest	Fruit weight (g)	Mean
Dhaka	0.44	0.56	0.70	0.21	0.21	0.46	0.58	0.41	0.29	0.46	0.43
Gazipur	0.64	0.64	0.49	0.42	0.45	0.46	0.53	0.64	0.32	0.53	0.51
Jashore	0.60	0.45	0.60	0.42	0.42	0.60	0.30	0.30	0.45	0.60	0.47
Khagrach-hari	0.67	0.54	0.61	0.42	0.42	0.72	0.53	0.55	0.57	0.63	0.57
*Manikganj	-	-	-	-	-	-	-	-	-	-	
*Sherpur	-	-	-	-	-	-	-	-	-	-	
*Tangail	-	-	-	-	-	-	-	-	-	-	
*Patuakhali	-	-	-	-	-	-	-	-	-	-	

Table 6: Diversity indices of quantitative traits of accession belonging to different collection sources.

High diversity indices in fruit length, days to harvest and fruit weight were found for Jashore and Khagrachari. Socio-economics along with unique climatic, edaphic and agronomic practices of hill ecosystem might be associated with the heterogeneity of germplasm of Khagrachari. Jashore, on the other hand, is one of the commercial vegetable growing spots of the country where farmers prefer high yielding varieties (HYV) and hybrids. Germplasm of Jashore might be of advanced cultivars (HYV) and/or hybrids. According to Bhandari (2017), HYV and hybrids lead to narrow genetic bases of crop varieties leading to genetic vulnerability which may be devastating in the context of changing climatic conditions [5]. The traditional practice of keeping seeds has been lost in Jashore due to the influence of seed companies and other market forces which are mainly profit oriented.

As shown in table 2, germplasm represented by 10 entries in Gazipur, five (05) newly collected and five (05) genebank source (identifying number starting with BD) which were previously collected from various agro-ecological zones of the country. The collection sites are socioeconomically as well as environmentally heterogenous because of geographic proximities or distances can influence diversity of landraces and wild relatives [8]. Gene bank accession are collections from diverse agro-ecological regions b of the country. Thus, the estimated diversity index of accessions belonging to Gazipur was higher.

The H for agronomic attributes of germplasm ranged from 0.21 to 0.72, with the highest index in attribute fruit length of Khagrachari followed by Jashore. The lowest diversity index (H`) in attributes days to male flower and pistillate flower was estimated 0.21 in germplasm belonging to Dhaka. Wider range of diversity indices among the germplasm collected from 10 districts were recorded in leaf length, days to staminate and pistilate flowers and days to harvest (Table 6). Reports of earlier studies suggests that physiological changes at cellular, organ and individual plant level occur in response to environmental heterogeneity [39]. Therefore, the observed diversity indices of germplasm in different districts might be due to adaptive responses.

Out of ten quantitative traits only one exhibited the lowest index 0.26 and this trait was days to first harvest which was followed by the index value 0.32 of the trait days to pistillate flower (Table 7). The remaining traits gave high diversity indices ranging from 0.50 (days to staminate flower) to 0.87 (fruit weight). Pooling of index of quantitative traits showed a diversity index value 0.63 indicates medium variability of the collection. The variation in diversity index could be due to distinctness of characters of landraces due to ecological isolation [39].

Constraints

Due to insufficient land availability and limited labor availability at PGRC, BARI, the number of germplasm had to be limited to 33. The management of gene bank data was not adequate enough for prioritizing and selecting candidate germplasm. In many cases, the information generated by the gene bank was not of much use. The academic backgrounds of working scientists of PGRC, BARI are mostly in the fields of genetics and plant breeding with knowledge and skills in variety development and technology generation. A national strategy for education and training on plant genetic resources for food and agriculture (PGRFA) which can take care of education should be developed with a sense of urgency. There are eight public agricultural universities which take care of higher education in all fields of PGRFA. Three general universities also have programs of higher education in advance fields of crop research like the tissue culture, genetic engineering, biotech etc.

Genotype	Internode length (cm)	Leaf length (cm)	Leaf width (cm)	Days to staminate flower	Days to pistilat flower	Fruit length (cm)	Fruit width (cm)	No. of fruits/pl	Days to harvest	Fruit weight (g)
BD-4241	7.78	15.73	16.86	38	45	17.6	5.2	8.5	86	252.4
BD-4260	5.32	14.29	18.26	36	43	17.2	4.6	7	86	237.5
BD-4321	6.75	13.53	16.09	36	45	12.8	4.8	6	89	246.8
BD-9764	6.45	13.73	18.53	36	48	10.6	4.6	8.5	86	186.7
BD-10104	4.48	15.13	17.93	36	43	14.3	5.3	5.5	84	235.5
BD-10954	9.62	14.49	16.56	38	48	10.2	5.3	6	84	208.5
AC-74	6.58	13.16	16.39	38	48	8.6	4.3	4.5	82	185.6
AC-100	6.45	15.49	18.03	42	50	4.8	4.2	3.5	86	85.6
AC-207	3.90	16.86	19.66	40	48	20.9	7.86	6.5	89	528
AC-245	5.12	10.99	15.29	40	50	7.6	3.7	5.5	80	206.2
AC-304	10.65	12.29	17.19	38	50	14.8	6.1	7	86	276.5
AC-356	2.62	14.19	16.59	38	52	9.5	4.7	7.5	89	248.7
AH-54	4.82	13.19	15.26	36	43	7.2	5.6	4.2	84	128.9
AH-59	5.02	11.12	13.26	36	43	6.9	5.7	4.2	84	120.9
AH-60	8.4	15.2	19.36	36	43	16.9	7.74	7.5	84	292.9
AH-61	6.26	11.73	16.33	36	43	17.3	6.16	3.5	86	250.8
AH-63	6.32	13.43	17.06	36	48	4.6	3.8	3.5	86	136.4
AH-66	5.02	7.39	8.29	36	43	10.4	4.8	4	84	242.8
AHI-35	7.12	12.53	16.29	36	43	14.6	4.9	7.5	84	304.8
AHI-70	4.98	9.06	13.26	36	43	16.1	5.1	3.5	86	365.7
AHI-83	6.25	11.63	14.93	36	43	11.8	5.2	8	80	235.8
AHI-94	8.95	12.29	15.76	36	43	12.9	4.3	4	80	195.6
IAh-117	6.65	12.03	14.63	38	48	13.2	4.6	6	86	165.8
IAh-126	4.75	7.93	10.06	42	52	12.4	5	4.5	86	280.6
IAH-273	5.62	11.46	15.62	36	50	6.9	5.2	4.5	84	320
IAH-274	6.08	12.7	14.78	36	50	7.8	5	3.5	86	275.8
IAH-275	5.38	11.62	14.82	42	50	7.2	4.9	3.5	86	308.7
IAH -297	8.95	12.29	15.76	36	43	12.2	5.3	4.5	80	230.6
IAH -299	8.32	11.73	14.49	42	52	10.8	4.8	4.5	86	330.4
IAH-323	8.82	12.53	13.96	42	52	8.6	6.2	3.5	89	385.2
IAH -327	5.45	9.16	11.73	36	48	7.8	6.2	3	84	375.6
IAH -331	9.85	10.06	12.09	38	43	14.3	4.1	5.5	80	208.7
AMA-406	6.2	13.62	18.4	40	50	21.8	8.08	3.5	86	570.5
H′	0.71(H)	0.65(M)	0.73(H)	0.50(M)	0.32(L)	0.87 (H)	0.75 (H)	0.76(H)	0.26(L)	0.78 (H)
Pooled diversity index (H′) = 63.30										

Table 7: Shannon Weaver Diversity index (H`) of germplasm under study.

Conclusion

The level of genetic diversity of the germplasm under this study probably is a consequence of environmental heterogeneity of collection sites due to geographical distance. Existing diversity would permit plant breeders to select superior genotypes either to be directly used as new varieties or to be used as parents in future hybridization programs. To provide genetic materials to plant breeders detailed and comprehensive information needs to be developed. Hence, initiatives should be taken to develop electronic methods of Genebank Information Management System (GBIMS) for germplasm management.

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