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CHARACTERIZATION AND DIVERSITY ANALYSIS OF HYACINTH BEAN COLLECTIONS IN BANGLADESH

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Abstract

The experiment was conducted with 150 accessions of Hyacinth bean (*Lablab purpureus* L. Sweet) of which 104 were from Bangladesh and 46 accessions from 17 countries of Asia, Africa and Europe for characterization and diversity analysis. Low to high Shannon-Weaver Diversity Index (0.14 to 0.99) were observed among the 16 qualitative characters. The genotypic and phenotypic coefficient of variations of 19 quantitative characters ranged from 3.59 to 4.08 % and 5.30 to 43.87%, respectively. The accessions were grouped into ten clusters ranging from 8 to 25 accessions. Accessions collected from the same districts in Bangladesh or countries were distributed into different clusters. The results obtained by D^2 analysis were also confirmed by canonical analysis. Crosses between accessions belonging to maximum divergent clusters of CPI 106548 (India), ILRI 14437 (Zimbabwe) and TOT 7905 (Uzbekistan) from cluster IX with accessions of BD 122 (Hobiganj, Bangladesh) and BD 8785 (Feni, Bangladesh) from cluster I, and BD 8770 (Gazipur, Bangladesh) from cluster VI for obtaining better variability to the subsequent generation. The breeder can use the selected accessions for varietal improvement of hyacinth bean.

Keywords: *Lablab purpureus*, characterization, cluster analysis, Bangladesh.

Introduction

Hyacinth bean is one of the important crops grown throughout the tropics and sub-tropics. It is a diploid legume (2n=2x=24), and a native to Asia and Africa. In Bangladesh, it is known as country bean or shim. It is consuming in various ways such as s young pods and immature seeds for vegetable purpose, dry seed is used as pulse soup. The most preferred types for vegetable are long pods, bold seeded with high pod fragrance (Venkatesha *et al*., 2013). Though vegetable production in Bangladesh is increasing day by day, it fails to keep pace with the ever increasing requirement. As hyacinth bean has a wide adaptability and immense genetic variability, there is an ample scope to breed for development of new varieties for winter as well as other season of the year. BARI released 8 varieties

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of hyacinth bean for winter and two varieties (BARI Shim-3 and BARI Shim-7) for both for summer and winter. Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh released 13 varieties of hyacinth bean. In addition, there are lots of landraces are cultivated all over the country. Hyacinth bean grown on approximately 17,126 ha of land across the country during the winter season and the average yield is 5.50 t/ha of fresh pods and total production is about 94,356 t (BBS, 2014). Bangladesh is rich in hyacinth bean diversity. Systematic research such as collection, conservation, characterization, evaluation, diversity, profitability study and utilization of hyacinth bean has been done at BARI (Islam *al.*, 2002; Islam, 2008; Islam *et al.*, 2010; Islam *et al*. 2014; Moniruzzaman *et al*. 2022). Characterization consists of recording those characters which are highly heritable, can be easily seen by the eye and are expressed in all environments. A number of plant exploration have been organized and a sizeable number of hyacinth bean germplasm collections have been made and maintained at various centres and countries. PGRC of BARI conserved 751 accessions including 46 exotic accessions in the gene bank. Few studies at both morpho-genetic and molecular level have been already done in different countries but none or few reports included germplasm from Bangladesh (Maass *et al*., 2005; Wang *et al*., 2007; Venkatesha *et al.*, 2013). A better utilization and a fuller exploitation of collected germplasm require better knowledge of the variability existing among the collections. The purpose of the study was to characterize the Bangladeshi and exotic accessions to know the genetic diversity and identify the important traits for varietal improvement of hyacinth bean.

Materials and methods

The experiment was conducted at Plant Genetic Resources Centre of BARI, Joydebpur, Gazipur, Bangladesh during August 2006 to May 2007. The location was at 24.00^0 N latitude, 90.26^0 E longitudes and 8.40 meter above sea level altitude. The mean temperature was 10.6^0C to 33^0C and relative humidity from 68.3% to 97.64% during the experiment. The soil of the experimental field was silty clay having a pH of 6.5. One hundred and four accessions from 39 districts of Bangladesh and 46 accessions from 16 countries of Asia, Africa and Europe were used in this study (Table 1and Fig.1). BARI Hyacinth bean-1 (BD 7774) and BARI Hyacinth bean-2 (BD 7775) were used as check variety. The accessions were selected from 20º35' to 26º75' N latitude and 88º03' to 92º75' E longitude in Bangladesh and on the basis of geographical location, qualitative and quantitative characters (Islam *et al*., 2002; Islam, 2008). The exotic accessions (1 to 8) were collected from AVRDC based on geographic origin namely, India, Lao Republic, Philippines, Thailand, Cambodia, Malaysia, Viet Num, Indonesia, Taiwan, Ethiopia, Zambia, Zimbabwe, Kenya, Mozambique, Denmark and Uzbekistan (Table 1 and Table 4). Among them, nine accessions namely CPI 34777, CPI 81626, CPI 106548, CPI 35894, CPI 52508, CPI 76996, CPI 100602, ILRI 13695 and ILRI 14437 were selected from core collection developed by Pengelly and

Maass (2001). All the accessions were conserved at the genebank of PGRC. Three seeds per accession were planted in polyethylene bag (6 cm in diameter approx.) containing a mixture of sandy-loamy soil and decomposed cow dung (1: 0.25) on 9 October 2006. The seedlings were transplanted on 17 October 2007. The experiment was conducted in Alpha Lattice Design with three replications and each replication consisted of three plants.

Table 1. Collection of hyacinth bean accessions from different country

Name of district	Number of accession	Name of district	Number of accession
Bangladesh			
Chittagong	14	Noakhali	2
Gazipur	7	Rajbari	2
Pabna	6	Rajshahi	2
Sirajganj	6	Sherpur	2
Cox's Bazar	5	Bandarban	1
Kushtia	5	Barguna	1
Natore	5	Barisal	1
Hobiganj	4	Comilla	1
Rangamati	4	Dinajpur	1
Jamalpur	3	Faridpur	1
Naogaon	3	Gaibandha	1
Nawbabgonj	3	Gopalganj	1
Chuadanga	2	Jessore	1
Feni	2	Jhalakati	1
Khagrachhari	2	Magura	1
Lakshmipur	2	Narail	1
Meherpur	2	Panchagarh	1
Moulvibazar	2	Patuakhali	1
Mymensingh	2	Rangpur	1
Netrakona	2	**Bangladesh total**	**104**
Exotic country			
Asia		Uzbekistan	1
India	8	**AFRICA**	**7**
Laos	6	Ethiopia	2
Philippines	6	Zambia	2
Thailand	5	Zimbabwe	1
Cambodia	4	Kenya	1
Malaysia	3	Mozambique	1
Viet Nam	2	**EUROPE**	**2**
Indonesia	1	Denmark	2
Taiwan	1	**Total-Country-17**	**150**

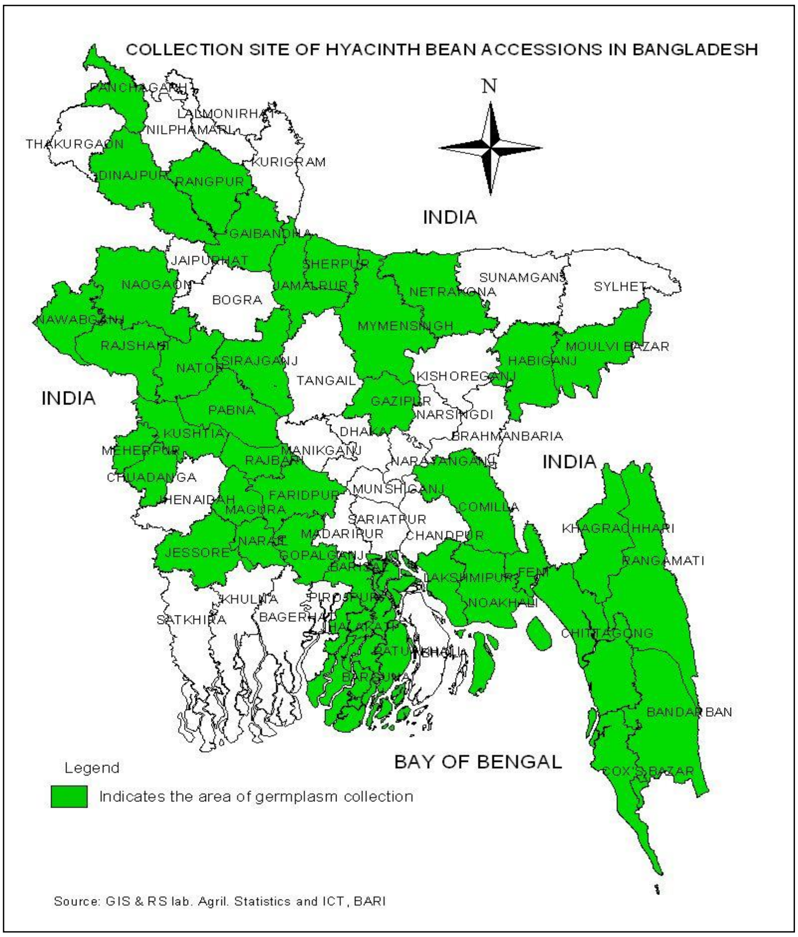

Fig.1. Collection site of 104 accessions of hyacinth bean from 39 districts in Bangladesh.

There were 15 blocks and each block consisted of 10 plots in each replication. The unit plot size was 2.2 X 2.5 m. The plants were given support of two meter height bamboo stick. The plants were initially irrigated by pipe and later on surface irrigation was given whenever required. The insecticides admire (0.5 ml per litre) was applied for controlling aphids and Vitavax-200 (2g per litre) was applied in the soil for controlling foot rot diseases. Manure and fertilizers were applied as 6 ton/ha cow dung, 50 kg N, 30 kg P, 45 kg K, 9 kg S and 1.5 kg B per hectare in the form of urea, triple super phosphate, murate of potash, gypsum and borax, respectively. Qualitative (16) and quantitative (19) characters were recorded as per AVRDC-GRSU data recording sheet (Table 2 and Table 3). Quantitative data were recorded from 30 randomly selected nine plants. Shannon-Weaver Diversity Index (SWDI) was measured in qualitative characters. H' ranges from 0 to 1, where 1 indicates the maximum diversity and was classified as low (H'<0.50), intermediate (H'=0.50-0.75) and high (H'≥0.75) based on Jamago (2000). Range, mean, genotypic and phenotypic coefficient of variation were calculated. Analysis of Variance, Principal Component Analysis, Principal Coordinate Analysis, Canonical Vector analysis and Cluster analysis were performed with MSTAT-C and Genstat 5 software.

Results and discussion

(i) Phenotypic diversity of qualitative characters

Light green (77%) and light purple (23%) hypocotyle and epicotyl colours were found among the 150 accessions of 17 countries in Asia, Africa and Europe (Table 2). The maximum percentage of accessions exhibited green colour (68-70%) and the minimum accessions showed purple colour (30-32%) of stem and leaf vein. Absent (2%) and present (98%) of leaf anthocyanin were observed. The colours of the hyacinth bean leaf were classified as light green (8%), medium green (68%) and dark green (24%). Green and purple colours were found in hypocotyl, epicotyl, main stem and leaf vein from the accessions of Bangladesh, Laos, Philippines and Thailand with different percentage. Only the green colour was found in all the accessions from India (8 accessions), Cambodia (4), Malaysia (3) and all the countries from Africa and Europe. Purple colour was found in the accessions from Indonesia (1), Taiwan (1), Uzbekistan (1) and Viet Nam (2). Ovate (11% accessions) and round (89%) terminal leaflet shapes were found. Pengelly and Maass (2001) was found green, purple and reddish stem among the 249 accessions of hyacinth bean from 5 countries in Asia and 13 countries in Africa. Sultana *et al.* (2001) reported light green, green, purple, red purple, light green with purple and green with purple stem, and green and purple leaf vein among the 107 accessions from 20 countries in Asia, Africa, South America and Europe. But in this study, both stem and leaf vein showed green and purple. Pengelly and Maass (2001) was found green and purple leaf while Sultana *et al.* (2001) and this study found light, medium and deep green leaf among the accessions. Indeterminate climber (99%) and determinate bushy (1%) growth habit were exhibited among the 150 accessions. Two determinate accessions such as BD 8529 and CPI 106548 were found in Ethiopia and India, respectively. Indeterminate character appeared to be the most abundant growth habit of lablab bean in Bangladesh. Shivashankar and Kulakarani (1989) classified the growth pattern into determinate types (156 accessions), indeterminate (50 accessions) and semi-determinate (15 accessions). They also concluded that the cultivated field types were mostly determinate and photo-insensitive while indeterminate types were spreading and photo-sensitive. Sultana *et al.* (2001) was found one determinate accession in India of their 107 accessions on morphological and physiological variation study in lablab bean. In an Indian lablab bean collection of 255 accessions, 11.37% determinate accession was reported by Shivashankar *et al.* (1977) while 1% determinate accession was found in this study. White and purple flowers were exhibited in the accessions in Bangladesh, India, Cambodia, Laos, Philippines, Thailand and Zambia. But only the white flower colour was noted from Malaysia and Denmark. Purple flowers were observed in Indonesia, Taiwan, Viet Nam and Uzbekistan. White, purple, mauve and pale lilac flowers were found by Pengelly and Maass (2001), where white, light purple and purple flowers were reported by Sultana *et al.* (2001) while white and purple flowers were found by the authors. The distribution of edible pod shape was flat (64.67%), elongate (20.67%), elongate-wavy (14%) and round (0.67%) while the curvatures of edible pod were slightly curved (78%), straight (15.33%) and curved (6.67%). Elongate and flat are the common edible pod shape of hyacinth bean among the countries. Elongate-wavy pods were found only in Bangladesh and it was about 14% of the total accessions. However, all the accessions from Malaysia, Indonesia, Laos, Taiwan, Uzbekistan, Viet Nam were exhibited flat shape and those from all other countries from Africa and Denmark. Only one accession (TOT 2465) from Thailand showed round pod. Slightly curved pod curvature was common for almost all the countries. Short, medium, long and thick edible pods were observed in the hyacinth bean population. Eight distinct seed colours viz black, brown, yellow-white, grayed-orange, purple, black with brown and cream, and brown with cream were observed at maturity stage after sun drying. Black and or grayed-orange seeds were found in all the 17 countries. Two accessions, CPI 81626 and CPI 106548A having purple seed colour were found in India. Three types of mosaic seeds such as black with brown or cream, and brown with cream were found only in Bangladesh. The shape of dry seeds was classified as cuboid, flat, kidney, ovoid and round. Flat seeds (41.33%) dominated the population and were followed by the ovoid seeds (39.33%). Flat and or ovoid seeds were found in all the countries. Four accessions of kidney shape were exhibited in Bangladesh. Small, medium and large seeds were observed in Bangladesh while the small and medium seeds were exhibited in India, Laos, Malaysia, Philippines, Thailand and Viet Nam. Only small seeds were found in Indonesia, Cambodia, Uzbekistan, Ethiopia, Kenya, Mozambique, Zambia, Zimbabwe and Denmark. Small, medium and large seeds were reported by Sultana *et al.* (2001) while the similar seed sizes were reported by the authors. Shannon Weaver Diversity Index was estimated for the phenotypic diversity in the vegetative and reproductive characters of hyacinth bean. The high phenotypic diversities (≥0.75) was observed in hypocotyle colour, epicotyle colour, main stem colour, leaf vein pigmentation, flower colour, pod beak shape, seed shape and seed size. Moderate diversities (0.50-75) were observed in leaf colour intensity, terminal leaflet shape, pod colour, pod shape, pod curvature and seed colour. While low diversities (<0.50) were observed in case of leaf anthocyanin and plant growth pattern (Table 2).

Table 2. Distribution and Phenotypic diversity index of qualitative characters in hyacinth bean accessions

Name of descriptor	Descriptor state	Frequency distribution	Frequency distribution (%)	SWDI
Hypocotyle colour	L.green	115	77	0.78 (H)
	L.purple	35	23	
Epicotyle colour	Light green	115	77	0.78 (H)
	Light purple	35	23	
Main stem colour	Green	102	68	0.90 (H)
	Purple	48	32	
Leaf vein pigmentation	Green	105	70	0.88 (H)
	Purple	45	30	
Leaf anthocyanin	Absent	147	98	0.14 (L)
	Present	3	2	
Leaf colour intensity	Dark green	36	24	0.73 (I)
	Medium green	102	68	
	Light .green	12	8	
Terminal leaflet shape	Ovate	17	11	0.51 (I)
	Round	133	89	
Plant growth pattern	Indeterminate climber	148	99	0.10 (L)
	Determinate bushy	2	1	
Flower colour	Purple	72	48	0.99 (H)
	White	78	52	
Pod colour	Green	90	60.00	0.73 (I)
	Green with purple sutuer	20	13.33	
	Purple	7	4.67	
	Yellow-green	23	15.33	
	Yellow green with purple sutuer	9	6.00	
	Violate	1	0.67	
Pod shape	Elongate	31	20.67	0.66 (I)
	Elongate-wavy	21	14.00	
	Flat	97	64.67	
	Round	1	0.67	
Pod curvature	Curved	10	6.67	0.60 (I)
	Straight	23	15.33	
	Slightly curved	117	78.00	
Pod beak shape	Long beak	41	27.33	0.99 (H)
	Medium beak	33	22.00	
	Short beak	41	27.33	
	Thick beak	35	23.33	
Seed colour	Black	65	43.33	0.62 (I)
	Brown	54	36.00	
	Yellow-white	5	3.33	
	Grayed-orange	20	13.33	
	Purple	2	1.33	
	Black+brown	1	0.67	
	Black+cream	1	0.67	
	Brown+cream	2	1.33	

Name of descriptor	Descriptor state	Frequency distribution	Frequency distribution (%)	SWDI
Seed shape	Cuboid	15	10.00	0.77 (H)
	Flat	62	41.33	
	Kidney	4	2.67	
	Ovoid	59	39.33	
	Round	10	6.67	
Seed size	Large	19	12.67	0.82 (H)
	Medium	93	62.00	
	Small	38	25.33	

Where, SWDI-Shannon-Weaver Diversity Index (H'); L=Low (H'<0.50), I= Intermediate (H'=0.50-0.75) and H= High (H'≥ 0.75)

(ii) Phenotypic and Genotypic Coefficient of Variability in Quantitative characters

The phenotypic and genotypic coefficient of variability among 19 quantitative characters are shown in Table 3. Analysis of variance indicated highly significant difference among the accessions for all characters. The highest terminal leaflet length was exhibited in BD 59 (14.34 cm, Natore, Bangladesh) while the lowest 8.43 cm in BD 8830 (Chittagong, Bangladesh). This indicated that leaflet length of BD 59 was almost two times larger than BD 8830. On the other hand, terminal leaflet width ranged from 8.23 (TOT 7217, Malaysia) to 12.95 cm (BD 59, Bangladesh) with an average of 10.28 cm. Terminal leaflet length and width ratio ranged from 0.97 to 1.23. The accessions produced first flower from 55 days (BD 7775, Bangladesh) to 107 days (BD 7967, Sirajganj, Bangladesh). On average, rachis length and peduncle length both were approximately 11.72cm. The accessions produced 1.71 (BD 8757, Rajshahi) to 14 flowering nodes per rachis (BD 8748, Rajshahi) with an intensity of node per cm was 1.53. The accessions exhibited 2.47 (PD 11, India) to 14 (BD 8748, Rajshahi) pods per rachis in the population. The edible pod length ranged from 4.92 to 16.74 cm in CPI 52508 (Mozambique) and BD 8808 (Sherpur, Bangladesh), respectively. On the contrary, pod width ranged from 1.35 to 4.36 cm in CPI 106548 (India) and BD 8018 (Kushtia, Bangladesh), respectively. The accessions produced pod weighing 2.1 to 17.07g in CPI 106548 and BD 8757, respectively. Such the lowest pod weight might be inherent characteristics of the accessions. The pod length and width ratio ranged from 1.94 to 9.09. The accessions produced 84 to 537 pods per plant from BD 8776 and TOT 3932 (Viet Nam), respectively while 2.83 to 5.57 seeds per pod were obtained from ILRI 13695 (Ethiopia) and BD 8738, respectively. The accessions produced an average of 300 pods per plant and 5 seeds per pod. The variation in number of pods per plant might be due to differences in number of inflorescence per plant, pods per raceme, flower dropping tendency and also due to the inherent potential of accessions (Mollah *et al.*, 1995). The accessions exhibited 0.90 to 1.60 cm seed length from CPI 106548 (India) and BD 8813, respectively while 0.68 to 1.21cm seed width was obtained from BD 8802 and BD

59, respectively. The seed length and width ratio ranged from 1.21 to 1.74 in BD 117 and BD 7974, respectively. The accessions exhibited 13.33g (CPI 106548) to 62g (BD 8770) of hundred seed weight with an average of 33.74g. The maximum phenotypic co-efficient of variation (PCV) was found in number of pods per plant (43.83%) followed by rachis length (40.98%), peduncle length (40.22%) and number of flowering nodes per rachis (38.57%), and minimum PCV was exhibited in leaf ratio (L:W) (5.30%). Sufficient variability was recorded among the Bangladesh accessions for the characters which could be used for genetic improvement of this crop. All the characters exhibited higher estimates of PCV than corresponding GCV. A similar situation was also noticed for genotypic and phenotypic variance. The relative efficiency of Alpha Lattice design over RCB design was more than 0.90. The LSD value of 19 characters are shown in Table 3.

Table 3. Phenotypic and genotypic coefficient of variability in hyacinth bean

Name of quantitative character	Range	Mean	GCV (%)	PCV (%)	LSD (5%)	F. Sign	REF F
Leaf length (cm)	8.43 - 14.34	11.15	7.25	9.38	1.07	1	0.94
Leaf width (cm)	8.23 - 12.95	10.28	6.94	8.96	0.94	1	0.95
Leaf ratio (L:W)	0.97 - 1.23	1.09	3.59	5.30	0.07	1	0.96
Days to 1st flowering	54 - 107	83.97	13.39	14.16	6.20	1	0.96
Rachis length (cm)	1.14 - 22.59	11.74	40.08	40.98	1.61	1	0.95
Peduncle length (cm)	1.69 - 22.86	11.72	39.01	40.22	1.84	1	0.99
No.of flowering nodes/ rachis	1.71 - 14.00	7.78	37.52	38.57	1.12	1	1.00
Node density (cm)	0.29 - 2.71	1.53	19.76	23.12	0.30	1	0.95
Number of pods per rachis	2.47 - 13.70	8.11	30.36	31.62	1.18	1	1.00
Edible pod length (cm)	4.92 - 16.74	9.48	22.01	22.87	0.95	1	0.97
Edible pod width (cm)	1.35 - 4.36	2.33	22.37	23.36	0.25	1	0.93
Edible pod weight (g)	2.10 - 17.07	7.04	33.82	34.93	0.99	1	0.94
Pod ratio (L:W)	1.94 - 9.09	4.32	36.35	36.92	0.45	1	0.94
Number of seeds per pod	2.83 - 5.57	4.51	9.30	11.56	0.50	1	0.94
Seed length (cm)	0.90 - 1.60	1.30	7.30	8.18	0.08	1	0.95
Seed width (cm)	0.68 - 1.21	0.90	8.61	9.49	0.06	1	0.95
Seed ratio (L:W)	1.21 - 1.74	1.44	6.67	8.02	0.10	1	0.95
Hundred seed weight (g)	13.33 - 62.00	33.74	26.90	28.34	4.83	1	0.96
Number of pods per plant	84.00 - 537	300.12	32.88	43.87	140.14	1	0.95
Number of pods per plant (Log transformation)	1.88 - 2.73	2.40	7.24	9.92	0.26	1	0.96

Where, REFF- Relative efficiency RCBD/Alpha Lattice adjusted; SWDI-Shannon Weaver Diversity Indices; F-Significance, 1= Significant at 1% level.

Pengelly and Maass (2001) found 4.0 to 16.5cm leaf length and 3.0 to 15.5cm leaf width while the authors observed 8.43 to 14.34 cm leaf length and 8.23 to 12.95cm leaf width. Comparatively higher rachis length (17.5cm in Australia and 28.1cm in Ethiopia), peduncle length (42.4 cm in Australia and 27.3cm in Ethiopia), lower flowering node density per rachis (0.6), pod length (2.5 to 14.0cm), pod width (1.6 to 3.2cm), pod ratio (2.2 to 7.3), seeds per pod (1 to 7) and hundred seed weight (5.7 to 10.35g) were reported by Pengelly and Maass (2001) than the present study. A good number of *Lablab purpureus* subsp. bengalensis were found among the 104 accessions from Bangladesh. They are characterized by elongated and elongated wavy types of edible pods. Probably, for this reason higher pod length, width, weight and number of seed per pod were exhibited in Bangladesh than the remaining region of the world. The higher rachis length and peduncle length in Australia and Ethiopia might be due to the longer vegetative growth in the field. Das (1990) recoded high variability among 92 accessions collected from Maharashtra State India and found late maturing groups were taller, had more leaves and with high green fodder yield. In Australia, much of the researches for the genetic improvement in lablab have been focused on improving the forage attributes (White bread and Pengelly, 2004). Likewise, much of the research efforts in Africa is towards development of cultivars for improving the soil properties by use as green manure crops (Maass *et al.*, 2010). Under Indian conditions, where the crop is mainly grown under specific short duration conditions for vegetable purpose, the most preferred traits would be short duration, photo insensitive, high pod and seed yield and higher test weight of seed (Venkatesha *et al.* 2013). Substantial variation for agro-morphological traits among lablab accessions was reported (Mahadevu and Byre Gowda, 2005; Islam 2008; Girish and Byre Gowda, 2009). The estimate of the higher PCV than corresponding GCV might be due to the higher degree of genotype x environment interaction. Little difference between GCV and PCV (<3.5%) were observed for the 18 characters studied indicating that the variability for these characters were primarily due to genotypic differences and selection for these characters were expected to be more effective. For the remaining character (i. e. number of pods per plant), big difference was observed between GCV and PCV (10.99%), environmental influences was pronounced and selection should be performed carefully considering environmental factors.

(iii) Genetic diversity in hyacinth bean

Genetic diversity of 150 accessions from 17 countries was grouped into 10 clusters using D^2 values (Table 4). Maximum number of accessions fell in 25 (Cluster-III) and the lowest 8 accessions was in Cluster VI . Clusters I, II, VI and VII contained the accessions of Bangladesh only. Cluster III was composed of the 18 accessions from Bangladesh and 7 accessions from 5 Asian countries like Cambodia (1 acc.), Laos (2), Thailand (2), Viet Nam (1) and Philippines (1). Cluster IV composed of the accessions from Bangladesh (8) and Thailand (1) and cluster V formed with the accessions of Bangladesh (15), India (2) and Thailand (1). Cluster VIII was formed with the accessions from Bangladesh (7 acc), India (CPI 81626), Kenya (CPI 100602) and Philippines (2 acc). Cluster IX was composed with 18 accessions from 11 countries from Asia like India (4), Cambodia (3), Indonesia (1), Malaysia (1), Taiwan (1) and Uzbekistan (1), from Europe, Denmark (2) and Africa, Ethiopia (1), Mozambique (1), Zambia (2) and Zimbabwe (1) and none accession from Bangladesh. It is mentioned that the six accessions of this cluster such as CPI 34777 and CPI 106548 (India), CPI 39894 (Denmark), CPI 52508 (Mozambique), CPI 76996 (Zambia) and ILRI 14437 (Zimbabwe) were aggregated the accessions from core collection (Pengelly and Maass, 2001). Cluster X was composed of the accessions from Bangladesh (7), Ethiopia (1), India (1), Laos (4), Malaysia (2), Philippines (3), Thailand (1) and Viet Nam (1). The maximum of 15 accessions from Chittagong districts (Bangladesh) were distributed among five clusters such as cluster I (3acc.), II (5), IV (1), VII (5) and VIII (1). Seven accessions from Gazipur were distributed among four clusters viz. cluster II (1), VI (4), VIII (1) and X (1) (Table 4). It may be mentioned that the two BARI released varieties namely BARI Hyacinth bean-1 and BARI Hyacinth bean-2 were distributed in clusters X and VIII, respectively. Accessions collected from the same geographic origin (districts or countries) were distributed into different clusters. In many cases, the accessions from different districts in Bangladesh or countries were accommodated in the same cluster indicating their close affinity. This result suggested that the accessions within a cluster might have some degree of ancestral relationship. The rich morphological diversity reported among the Bangladesh accessions in the present study can be effectively used for genetic improvement. Clustering of genotypes from different eco-geographic locations into one cluster was attributed to the free exchange of breeding materials from one place to another. The intra-cluster distance ranged from 0.88 (Cluster VI) to 1.62 (cluster VIII) (Table 5). This showed cluster VIII to be more heterogeneous than the other clusters.

Table 4. Distribution of different accessions in different clusters of hyacinth bean

Cluster	BD	Exotic	Total	Accessions with their origin (Country or district in Bangladesh)
Clu-I	13	0	**13**	BD 31-Pabna; BD 57, BD 60-Natore; BD 82-Rangpur; BD 90-Naogaon; BD 137, BD 799-Chittagong; BD 8001-Rangamati; BD 1739-Luxmipur; BD 1740-Noakhali; BD 8044, BD 122 (15)-Hobiganj; BD 8785 (84)-Feni
Clu-II	17	0	**17**	BD 113, BD 117-Hobiganj; BD 1785-Netrakona; BD 1830-Lakshmipur; BD 2880, BD 2917, BD 7995, BD 7998, BD 8855-Chittagong; BD 2884-Khagrachhari; BD 7999, BD 8857-Cox's Bazar; BD 8812-Moulvibazar; BD 8816-Bandarban; BD 8823, BD 8830-Rangamati; BD 8870-Gazipur
Clu-III	18	7	**25**	BD 128-Dinajpur; BD 1780, BD-7985-Mymensingh; BD 1816-Gopalganj; BD 7974, BD 7977-Sirajganj; BD 7988-Faridpur; BD 7992-Rajbari; BD 8005-Jessore; BD 8022-Kushtia; BD 8027-Meherpur; BD 8729-Pabna; BD 8738-Natore;

Cluster	BD	Exotic	Total	Accessions with their origin (Country or district in Bangladesh)
				BD 8746, BD 8749, BD 8752-Nawabganj; BD 8748-Rajshahi; BD 8787-Jamalpur; Bangladesh, CAM-372-Cambodia; TOT 7016, TOT 7017-Laos; TOT 2465, TOT 5648-Thailand; TOT 4772-Viet Nam; PHL 2663-Philippines
Clu-IV	8	1	**9**	BD 1792-Netrakona; BD 7967, BD 7968, BD 7978-Sirajganj; BD 8006-Narail; BD 8725-Chittagong; BD 8726-Pabna; BD 8802- Jamalpur; TOT 2454-Thailand
Clu-V	15	3	**18**	BD 6-Comilla; BD 86-Gaibandha; BD 1809-Jhalakati; BD 7982-Sirajganj; BD 7993-Rajbari; BD 8008, BD 8018, BD 8020, BD 8023-Kushtia; BD 8033-Meherpur; BD 8034, BD 8039-Chuadanga; BD 8737-Natore; BD 8757-Rajshahi; BD 8797-Jamalpur; PD-11, PER-12-India; TOT 0583-Thailand
Clu-VI	8	0	**8**	BD 59-Natore; BD 101-Naogaon; BD 114-Hobiganj; BD 8767, BD 8770 (81), BD 8775, BD 8776-Gazipur; BD 8813-Moulvibazar
Clu-VII	11	0	**11**	BD 100-Naogaon; BD 132, BD 135, BD 2907, BD 8832, BD 8867-Chittagong; BD 2887-Rangamati; BD 8815, BD 8831, BD 8849-Cox's Bazar; BD 8849-Khagrachhari
Clu-VIII	7	4	**11**	BD 130-Panchagarh; BD 1799-Barguna; BD 1818-Barisal; BD 7775-Gazipur; BD 8727-Pabna; BD 8808-Sherpur; BD 8810-Chittagong; CPI 81626 A-India; CPI 100602-Kenya; PHL 2622, PHL 263-Philippines
Clu-IX	0	18	**18**	BD 8529-Ethiopea; CPI 34777, CPI 81626 B, CPI 106548 A, CPI 106548 (111)-India; CPI 35894, CPI 35894 B-Denmark; CPI 52508-Mozambique; CPI 76996 A, CPI 76996 B-Zambia; CAM-177, CAM-177, CAM-372-Cambodia; ILRI 14437 (122)-Zimbabwe; LV 4018-Indonesia; TOT 7217-Malaysia; TOT 4881-Taiwan; TOT 7905 (148)-Uzbekistan
Clu-X	7	13	**20**	BD 111-Magura; BD 1805-Patuakhali; BD 1839-Noakhali; BD 8733, BD 8735-Pabna; BD 8809-Sherpur; BD 8835-Gazipur. ILRI 13695-Ethiopia; PD-13-India; TOT 4008 A, TOT 4008 B, TOT 4008 C, TOT 7654-Laos; TOT 0072, TOT 7118-Malaysia; PHL 2635, PHL 2648, PHL 3107-Philippines; TOT 2464-Thailand; TB-90-Viet Nam
Total	**104**	**46**	**150**	

*BD **Accession number:** 'BD' letter has been used before the number to identify the accession that comes from the PGRC, BARI, Gazipur, Bangladesh.

Table 5. Intra-and Inter cluster distance of different accessions in hyacinth bean

Name of cluster	Cluster-I	Cluster-II	Cluster-III	Cluster-IV	Cluster-V	Cluster-VI	Cluster-VII	Cluster-VIII	Cluster-IX	Cluster-X
Cluster-I	**1.06**									
Cluster-II	2.63	**0.97**								
Cluster-III	7.53	4.92	**1.15**							
Cluster-IV	5.57	4.32	5.19	**1.36**						
Cluster-V	9.69	8.06	6.27	4.14	**1.38**					
Cluster-VI	6.02	6.39	8.84	3.71	6.41	**0.88**				
Cluster-VII	4.05	1.45	3.49	3.79	7.06	6.64	**1.05**			
Cluster-VIII	11.22	9.02	5.33	6.24	3.30	9.35	7.68	**1.62**		
Cluster-IX	12.14	9.65	4.97	8.01	5.98	11.50	8.20	2.80	**1.12**	
Cluster-X	9.18	6.70	2.33	5.36	4.74	9.01	5.26	3.05	2.96	**1.15**

Where, Diagonal and bold indicate intra cluster distance

Maximum inter cluster distance was estimated between clusters I and IX (12.14) followed by clusters VI and IX (11.50), suggesting wide diversity between the accessions of these groups. On the contrary, the minimum inter-cluster distance was observed between clusters II and VII (1.45) indicated close relationship. Accessions in cluster VI showed maximum of leaf length, width and leaf ratio, fresh pod length, pod weight and pod ratio (L:W) and number of seeds per pod (Table 6). This cluster exhibited minimum for length of rachis and peduncle, number of flowering nodes per rachis and pods per rachis. White flower (88%), elongate with green edible pod (100%) and brown seed (100%) were exhibited from cluster VI. The accessions are *L. purpureus* ssp. bengalensis type and thus must be considered useful parental material. Cluster IX exhibited minimum for leaf length, width and leaf ratio, pod length, width, weight and pod ratio, number of seeds per pod, seed length and width, hundred seed weight and number of pods per plant. This cluster exhibited maximum for flowering node density. White and purple flower (both 50%); green (50%), yellow-green (32%), yellow-green with purple suture, purple and violate (each 6%) types edible pod colour; black (50%), grayed-orange (38%), yellow-white (6%) and purple (6%) seed colour were exhibited from cluster IX. The 18 accessions from 11 countries of Asia, Africa and Europe including 5 accessions from core collection were aggregated into this cluster. Clusters I and II exhibited for late flowering and the maximum number of pods per rachis, respectively. Narrow pod width was exhibited from clusters III and IX. The broad pod was from cluster IV. Neither a maximum nor a minimum value of the characters was exhibited from the accessions of clusters V and X. The highest length of rachis and peduncle, number of flowering nodes per rachis, length and width of seed, hundred seed weight and number of pods per plant were found in cluster VII. Early flowering accessions including BARI hyacinth bean-2 were observed in cluster VIII (Table 6).

Table 6. Cluster mean of different characters in hyacinth bean

Name of characters	Cl.-I	Cl.-II	Cl-II	Cl-IV	Cl.-V	Cl.-VI	Cl.-VII	Cl-VIII	Cl-IX	Cl-X
Leaf length (cm)	11.79	11.48	11.52	11.04	10.81	**13.05****	10.86	11.09	**9.81***	11.01
Leaf width (cm)	10.65	10.51	10.74	10.37	10.11	**11.52****	9.71	10.10	**9.28***	10.18
Leaf ratio (L:W)	1.11	1.09	1.07	1.06	1.07	**1.13****	1.12	1.10	**1.06***	1.08
Days to 1st flowering	**102.53****	93.90	89.34	100.97	79.26	93.03	76.93	**63.47***	69.56	77.82
Rachis length (cm)	11.55	13.41	15.44	5.57	4.81	**4.29***	**16.67****	10.99	14.52	12.97
Peduncle length (cm)	12.10	14.55	15.10	4.95	4.96	**4.24***	**17.48****	11.07	13.12	12.90
Number of flowering nodes per rachis	8.68	10.05	10.18	3.82	3.28	**2.71***	**10.77****	7.17	7.74	8.83
Flowering node density (cm)	**1.34**	1.35	1.53	1.54	1.48	1.61	1.55	1.51	**1.89****	1.51
Number of pods per rachis	7.87	**9.88****	9.60	5.39	4.57	**4.09***	8.94	7.12	9.82	9.50
Pod length (mm)	8.42	8.91	10.44	10.90	9.96	**12.76****	9.53	10.83	**6.26***	9.18
Pod width (mm)	2.50	2.55	**1.98***	**2.76****	2.72	2.21	2.26	2.40	1.98*	2.28
Pod weight (g)	7.16	7.58	5.93	9.05	8.92	**10.82****	7.56	8.69	**3.24***	6.00
Pod ratio (L:W)	3.40	3.55	5.66	4.26	4.08	**6.00****	4.29	4.86	**3.16***	4.24
Number of seeds per pod	4.18	4.30	4.77	4.55	4.66	**5.03****	4.37	4.79	**4.03***	4.54
Seed length (cm)	1.40	1.37	1.27	1.31	1.30	1.46	**1.48****	1.29	**1.11***	1.22
Seed width (cm)	1.04	0.99	0.84	0.89	0.89	1.03	**1.06****	0.88	**0.77***	0.84
Seed ratio (L:W)	**1.35***	1.38	**1.52****	1.46	1.47	1.43	1.39	1.47	1.43	1.46
Hundred seed weight (g)	51.89	45.64	24.69	30.23	30.28	52.88	**53.76****	30.08	**18.20***	25.14
Number of pods plant (log2)	2.13	2.37	2.52	2.26	2.40	2.05	**2.26****	2.43	**2.58***	2.56
Flower colour	1.38	1.53	1.28	1.44	1.83	**1.12***	1.27	**1.73****	1.50	1.55
Pod colour	1.62	1.94	1.56	1.56	1.94	**1.00***	2.09	2.09	2.00	**2.10****
Seed colour	**2.69****	2.12	1.76	1.67	**1.44***	2.00	2.27	1.64	2.17	1.90

Within rows, * and ** indicate minimum and maximum cluster mean values, respectively.

Both PC1 and PC2 were heavily weighted by length and width of leaf and seed, and leaf ratio (Table 7). However, PC1 heavily weighted for fresh pod width and PC2 for number of pods per plant. The cluster constellations obtained by D^2 analysis were confirmed by canonical analysis. Cluster constellations were also independently derived by using principal component analysis (PCA) to verify grouping obtained through D^2 statistic in a two-dimensional chart (PC1-PC2). In principal component analysis PC1, PC2 and PC3 were observed to contribute 56.29, 23.61 and 13.68%, respectively of the total divergence. Accession scores obtained for the first two components were plotted on two main axis and then superimposed on the clustering found from D^2 analysis (Fig. 2), showing the similar results. The maximum distance was observed between accessions BD 8785 (84) of cluster I collected from Feni district (Bangladesh) and CPI 106548 (111) of cluster IX from India (Fig.2). The accessions were comparatively close to each other in cluster VI and those in cluster VIII were most heterogeneous through scatter diagram. The results obtained by principal component analysis were reconfirmed by D^2 analysis. Accessions collected from the same geographic origin (districts or countries) were distributed into different clusters. The absence of relationship between genetic and geographic diversity suggests that forces other than geographic origin, such as exchange of breeding material, genetic drift, variation, natural and artificial selection are responsible for diversity. Similar findings were obtained in previous study by Sultana *et al.* (2001). Basavarajappa and Gowda (2000) grouped the 144 germplasm lines from India into 15 clusters based on D^2 values. The clustering pattern followed their respective geographic origin and variation between clusters might have resulted from the possible genetic drifts and selection. Plant populations restricted to small geographic areas or subjected to identical environmental pressures help to evolve adaptive gene complexes. These gene complexes are conserved by genetic linkages or stringent natural or human selections. The clustering of accessions from different ecographic locations into one cluster could be attributed to the free exchange of breeding materials between regions.

The magnitude of heterosis and potential for transgressive segregation largely depends on the degree of genetic diversity in the parental lines. The greater distance exists between two clusters, the wider the genetic diversity between their accessions. Good variation for genetic improvement of vegetative traits have been found among the Bangladesh accessions. The diverse accessions from exotic collections may be used in breeding programs to introduce novel genes/traits such to the Bangladesh accessions. Apart from exotic collections, some Bangladesh accessions such as BD 122, BD 8785, BD 8770 were placed near to yield attributing traits indicating their superiority for these traits. The result suggests scope for using these germplasm in breeding programmes for developing of lines with high yield and related traits. The results of phenotypic diversity analysis using qualitative traits were equally effective and promising for detecting of diversity at morphological level.

Table 7. Relative contribution of different characters in hyacinth bean

Name of characters	PC1	PC2
Leaf length (cm)	0.834	0.968
Leaf width (cm)	-0.924	-0.943
Leaf ratio (L:W)	-2.847	-2.115
Days to 1st flowering	-0.175	-0.047
Rachis length (cm)	0.140	-0.166
Peduncle length (cm)	0.031	-0.153
Number of flowering nodes per rachis	-0.288	-0.169
Node density (cm)	-0.117	1.054
Number of pods per rachis	-0.068	-0.151
Fresh pod length (mm)	0.114	-0.175
Fresh pod width (mm)	0.619	0.425
Fresh pod weight (g)	-0.084	0.147
Fresh pod ratio (L:W)	-0.053	0.376
Number of seeds per pod	0.202	0.215
Seed length (cm)	-1.934	-1.438
Seed width (cm)	1.295	-1.084
Seed ratio (L:W)	0.187	0.166
100- seed weight (g)	-0.137	0.080
Number of pods plant	0.322	0.896
Flower colour	-0.004	0.336
Fresh pod colour	-0.143	-0.002
Seed colour	-0.090	-0.016

Where, PC1-Principal component one, PC2- Principal component two

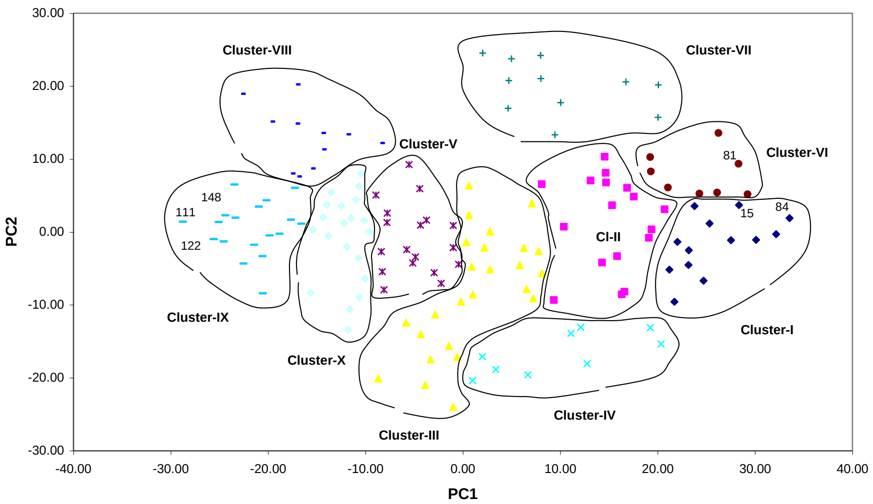

Fig. Distribution of different accessions in different clusters in hyacinth bean.

Conclusion

One hundred and fifty accessions from 17 countries of Asia, Africa and Europe showed low to high Shannon-Weaver Diversity Index (0.14 to 0.99) among the qualitative characters. The GCV ranged from 3.59 to 32.88% among the quantitative characters indicated considerable variability in hyacinth bean accessions. The accessions were grouped into ten clusters. Genetic diversity of the accessions did not show clear relationship with their place of collection. The crosses should be made between the accessions in cluster IX with accessions in cluster I and cluster VI. The breeder can use the selected accessions for varietal improvement of hyacinth bean.

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