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Diversity of common bean in Jammu and Kashmir, India: a DIVA-geographic information system and cluster analysis

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Abstract: A total of 80 diverse germplasm accessions of common bean (*Phaseolus vulgaris* L.) were collected from 31 different locations known for marginal and risk prone farming systems in remote and hilly areas of North-Western Indian Himalayan state of Jammu and Kashmir. The variability was observed in seed color, shape, size and 100-seed weight. Thirteen colors of bean seeds were represented in these 80 accessions with high predominance of red colored seeds. Cuboid, kidney and oval seed shapes observed were represented respectively in 61.25%, 25% and 13.75% of the accessions. There were significant variations in seed length, width and 100-seed weight being highly significant in the later case. All the three seed size classes (small, medium and large according to CIAT categorization) were represented in the collected accessions. 22.5% accessions have 100-seed weight less than 25g, 53.75% accessions have 100-seed weight between 25-40g while 100-seed weight of more than 40g was recorded in 23.75% of the accessions. Highly positive correlations were found between 100-seed weight and seed length and width and between seed length and seed width. The 80 accessions were grouped in three clusters at a coefficient level of 0.3 with largest cluster of 59 accessions followed by a medium cluster with 20 accessions and the least with a single accession. Grid maps generated through DIVA-GIS software indicated that diverse accessions of common bean in terms of seed size and weight can be sourced from the areas falling in Budgam, Shopian and Kulgam districts of the state. Conservation of this remarkable genetic diversity is recommended for future propagation, breeding and the investigation of the genetic relationships.

Keywords: Cluster analysis, Common bean, DIVA-GIS software, Germplasm, *Phaseolus vulgaris*

INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is the most important legume worldwide for direct human consumption, the crop is consumed principally for its dry (mature) beans, shell beans (seeds at physiological maturity), and green pods. It provides 15% of the protein and 30% of the caloric requirement to the world's population and represents 50% of the grain legume consumed worldwide (McConnell, 2010). Dry beans are regarded as an important functional food containing high levels of chemically diverse components (phenols, resistance starch, vitamins, fructo-oligosaccharides) giving protection against such conditions as oxidative stress, cardiovascular diseases, diabetes, metabolic syndrome and many types of cancer (Camara *et al*., 2013).Dry bean is truly a "new world crop" originating some 7000 years ago in two different parts of the North and South American continents(Landon,2008). The clear separation of the two domestication centers, i.e., Mesoamerica (southern Mexico and Guatemala) and regions along the Andes mountain range(principally Peru and Columbia) resulted in the small seeded (< 25 g/100 seeds) Mesoamerican beans and the large seeded (> 40 g/100 seeds) Andean gene pools (Singh *et al*. 1991). Middle American germplasm of common bean is considered to be more complex and that more than 60% of common bean production worldwide is derived from cultivars of Middle American origin (Beebe *et al*., 2000). Recent studies show that close wild relatives of *P. vulgaris* are distributed throughout the Mesoamerican region showing a higher diversity than in the Andean gene pool (Bitocchi *et al*., 2012). In a latest and interesting study on 27 common bean accessions, analyzed using thirteen morphological traits, the Andean accessions were found to be less diverse than the Mesoamerican accessions (Hegay *et al*., 2014). Both the gene pools followed parallel pathways of dissemination through the world, generating new secondary centers of diversity in Africa and Asia (Blair *et al*., 2012). It was not until the 15th – 16th century that dry beans crossed the Atlantic Ocean. Spanish and Portuguese explorers first transported dry beans to Europe and Africa respectively where beans then spread rapidly to rest of the world. Dry beans have since evolved into multiple types and are now grown and consumed in most parts

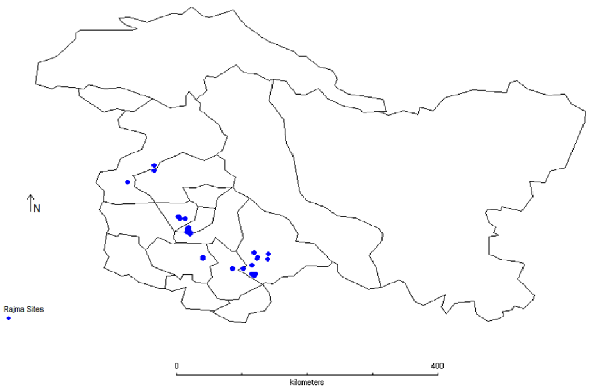

Fig. 1. *DIVA-GIS mapping of collection sites of P. vulgaris germplasm from Jammu and Kashmir, India.*

Fig. 2. *Diversity in seed color and shape of P. vulgaris germplasm collected from Jammu and Kashmir, India.*

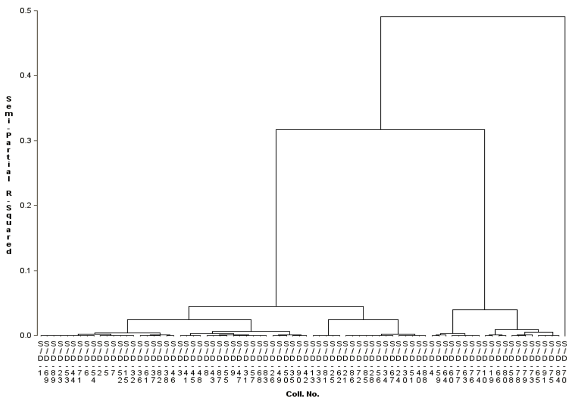

Fig. 3. *Dendogram obtained by cluster analysis showing the similarity rate of 80 common bean accessions. Accession codes are given in table 2.*

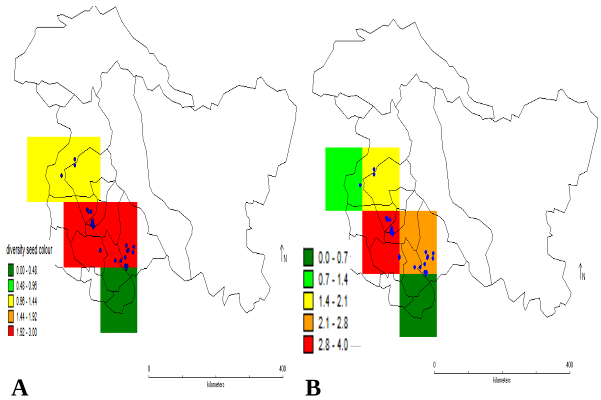

Fig. 4. *Grid maps showing diversity of seed color (A) and seed length (B) in P. vulgaris germplasm collected from Jammu and Kashmir, India.*

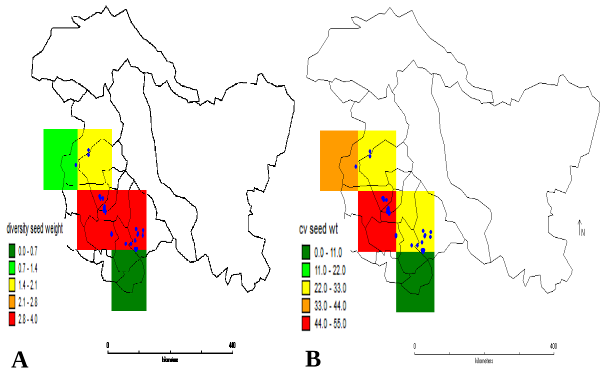

Fig. 5. *Grid maps showing diversity of seed weight (A) and CV seed weight (B) in P. vulgaris germplasm collected from Jammu and Kashmir, India.*

of the world. Common bean is hence widely distributed having broadest range of genetic resources (Singh, 1999) and is a staple food in Latin America, Africa and India (Xu and Chang, 2009). Currently, Brazil is the No. 1 producer of dry beans growing on an average 3.2 million metric tons (mmt) annually followed by India, Myanmar and China growing approximately 3.0 mmt, 1.7 mmt and 1.2 mmt respectively (FAO website).

In India common bean (Local "*Rajmash*") is grown mainly in the states of Maharashtra, Jammu and Kashmir, Himachal Pradesh, Uttar Pradesh, Tamil Nadu (Nilgiri Hills, Palani Hills), Kerala (Parts of Western Ghats), Karnataka (Chickmagalur Hills) and West Bengal (Darjeeling Hills). North-Western Indian Himalayan state of Jammu and Kashmir (33°17′–37° 20′ N latitude, 73°25′–80°30′ E longitude) exhibits a great variation in the physiographic features and agro-climates at macro and micro-level, involving cold arid, temperate, intermediate and sub tropical zones, within a small geographical area of 2.22 lakh sq. km. indicating the inherent agricultural potential of the state. A general decline in the area under cultivation as well as production of pulses in general and common beans in particular has been recorded in the state during last three decades. Local common bean genotypes maintained by farmers of the state for generations display a wide range of seed and color patterns contributing to the genetic resource. The collection and preservation of these genetic resources thus, is a challenge for the future, as these represent a source of variation that can be useful in crop science or breeding programs to improve seed quality. Application of geographic information systems (GIS) and ecogeography in plant genetic resources that began in the 1990s has generated much interest in the last two decades. GIS are useful to manage and analyze geographical data, such as passport collection data and environmental variables and have now become best tool to perform ecogeographical analyses (Parra-Quijano *et*

Table 1. Collection sites of *P. vulgaris* germplasm in Jammu and Kashmir, India.

Name of village (Collection sites)	District	Province	Latitude	Longitude	Accessions collected
Gool Gulabgarh	Ramban	Jammu	33°15′	75°00′	06
Sarsi	Doda	Jammu	33°06′	75°25′	04
Chirala	Doda	Jammu	33°14′	75°54′	02
Renda Bhaderwah	Doda	Jammu	32°59′	75°43′	01
Chinta Chenchoda Bhaderwah	Doda	Jammu	33°01′	75°44′	01
Balot Bhaderwah	Doda	Jammu	33°01′	75°42′	01
Bhalra Bhaderwah	Doda	Jammu	33°01′	75°41′	03
Seeri Bhaderwah	Doda	Jammu	33°06′	75°34′	01
Prem Nagar	Doda	Jammu	33°09′	75°41′	01
Drabshala Surror	Kishtwar	Jammu	33°15′	75°45′	01
Angara Sarthal	Kishtwar	Jammu	33°16′	75°46′	01
Bidha	Kishtwar	Jammu	33°19′	75°55′	05
Thakraie	Kishtwar	Jammu	33°20′	75°43′	01
Muqam	Budgam	Kashmir	33°53′	74°40′	01
Dembal	Budgam	Kashmir	33°53′	74°40′	04
Rakhi-e-hai	Budgam	Kashmir	33°51′	74°45′	02
Hangoo	Budgam	Kashmir	33°53′	74°39′	02
Surasyar	Budgam	Kashmir	33°53′	74°40′	01
Brenwar	Budgam	Kashmir	33°53′	74°40′	01
Wangwas	Budgam	Kashmir	33°51′	74°41′	08
Hirpora	Shopian	Kashmir	33°41′	74°48′	06
Padpawan	Shopian	Kashmir	33°41′	74°48′	03
Devpora	Shopian	Kashmir	33°42′	74°47′	01
Tooli Halan Seadow	Shopian	Kashmir	33°39′	74°46′	01
Cheke Chotipora Seadow	Shopian	Kashmir	33°40′	74°47′	01
Shadab Karewa	Shopian	Kashmir	33°43′	74°48′	04
Kawa Tekri Asnoor	Kulgam	Kashmir	33°37′	74°49′	02
Asnoor	Kulgam	Kashmir	33°38′	74°50′	06
Hatcha Marg Handwara	Kupwara	Kashmir	34°24′	73°57′	03
Nagsari Kalaroos	Kupwara	Kashmir	34°34′	74°19′	02
Muhri	Kupwara	Kashmir	34°39′	74°19′	04

al., 2012). DIVA-GIS is a statistical software designed to assist the plant genetic resources and biodiversity communities to map the range of distribution of species in which they are interested (Hijmans *et al*., 2002). In addition to the typical utilities of a GIS, this software has specific tools that allow to easily create richness maps, to select areas for *in situ* conservation or to generate EcoCrop models. The present investigation was aimed at collecting and assessing the genetic diversity of local common bean germplasm. We have attempted to use cluster analysis and DIVA-GIS software to assess the genetic diversity of the collected germplasm using some seed traits.

MATERIALS AND METHODS

Collection of germplasm: An exploration and germplasm collection programme of *Phaseolus vulgaris* was undertaken in different remote and hilly areas of Jammu and Kashmir in collaboration with Sher-e-Kashmir University of Agricultural Sciences & Technology, Kashmir during the months of September/ October, 2013. A total of 80 different accessions were collected mostly from the fields and sometimes from farmer's store following a random sampling procedure. Each accession was assigned a specific collector number at the time of collection. The values of latitude and longitude of collection sites were recorded using the Global Positioning System (Garmin GPS-12). Local people especially the elderly ones were interviewed for generating information about ethnic and unique features and other relevant information about the collected material.

Data collection and statistical analysis: Data were recorded on seed color, seed shape, seed length, and seed width and 100-seed weight. Seed length and width was recorded in 30 randomly selected seeds in each accession using Mitutoyo digimatic calipers (Mitutoya Corporation, Japan). Mean values recorded for quantitative traits were analyzed following standard statistical techniques (SAS Enterprise Guide 4.2 version). Correlation coefficients for the quantitative traits studied were determined using SAS.

Cluster analysis: To assess the magnitude of genetic diversity available in common bean germplasm, minimum variance dendrogram has been generated using the SAS Enterprise Guide (4.2 version). Genetic diversity is an important factor for any heritable improvement and the knowledge of genetic diversity is useful for selecting desirable genotypes from common

Table 2. Seed color, shape, length, width and test weight observed in germplasm of *P. vulgaris* collected from Jammu and Kashmir, India

Accession No.	Color	Shape	Length (mm)	Width (mm)	100- Seed weight (g)
S/D-1	Dark Red	Cuboid	13.0	8.0	30.0
S/D-2	Bluish	Kidney	13.8	7.4	33.0
S/D-3	Black	Cuboid	9.2	6.4	23.2
S/D-4	Dark red	Oval	12.5	9.1	61.4
S/D-5	Cream Khaki stripes	Cuboid	13.5	7.7	30.9
S/D-6	Khaki green	Kidney	13.2	7.4	28.4
S/D-7	Brownish	Cuboid	11.9	6.9	30.4
S/D-8	Brownish	Cuboid	11.8	7.8	25.6
S/D-9	Dark red	Oval	10.4	6.7	26.4
S/D-10	Reddish	Cuboid	13.2	7.9	37.6
S/D-13	White	Oval	8.3	5.3	14.4
S/D-15	Brownish	Cuboid	12.0	7.9	28.8
S/D-19	Reddish	Cuboid	13.5	7.8	37.3
S/D-21	Reddish	Cuboid	12.0	7.8	28.8
S/D-23	Dark red	Cuboid	12.0	7.0	30.0
S/D-24	Reddish	Cuboid	10.9	7.2	33.6
S/D-25	White	Oval	8.2	5.8	18.4
S/D-26	Cream white	Kidney	9.4	5.8	18.8
S/D-28	Reddish	Cuboid	10.9	6.3	28.8
S/D-30	Reddish	Cuboid	10.4	6.9	33.2
S/D-31	Dark red	Cuboid	10.9	6.9	24.0
S/D-32	Brownish	Ciuboid	11.9	7.5	28.8
S/D-33	White	Oval	8.2	5.3	16.4
S/D-34	Reddish	Cuboid	11.5	7.4	26.0
S/D-35	Light purple	Cuboid	11.2	7.0	22.0
S/D-36	Dark yellow	Kidney	13.2	7.3	34.4
S/D-37	Khaki green	Kidney	13.7	7.3	34.0
S/D-38	Brownish	Cuboid	12.5	8.0	36.8
S/D-40	Reddish	Cuboid	12.5	7.4	32.0
S/D-41	Black	Cuboid	10.3	5.9	21.6
S/D-42	Khaki green	Cuboid	11.3	7.3	24.4
S/D-43	Brownish	Cuboid	11.3	7.4	26.4
S/D-44	Cream white	Cuboid	12.1	7.2	29.2
S/D-45	Black	Kidney	11.2	6.9	24.4
S/D-46	Cream white	Cuboid	11.1	7.4	35.2
S/D-47	Dark red	Kidney	11.5	7.5	25.6
S/D-48	Black	Cuboid	12.3	7.1	24.4
S/D-49	Dark red	Cuboid	11.1	6.6	21.2
S/D-50	Dark red	Cuboid	11.9	6.8	22.4
S/D-51	Reddish	Kidney	10.3	6.4	31.6
S/D-52	Brownish	Cuboid	11.5	7.3	31.2
S/D-53	Dark yellow	Cuboid	12.0	7.0	30.4
S/D-54	Khaki	Kidney	11.8	7.2	29.6
S/D-55	Bluish	Cuboid	12.0	7.0	25.6
S/D-56	Yellow	Kidney	11.8	6.9	30.4
S/D-57	Cream white	Cuboid	10.9	6.7	24.4
S/D-58	Brown mottled	Cuboid	14.6	7.9	49.3
S/D-59	Dark red	Kidney	15.8	7.0	62.8
S/D-60	Dark red	Kidney	16.6	8.3	57.2
S/D-61	Dark red	Cuboid	13.3	7.7	33.2
S/D-62	White	Oval	8.9	6.2	20.8
S/D-63	Dark red	Cuboid	12.9	9.1	57.7
S/D-64	Light speckled	Kidney	16.4	8.8	64.8
S/D-65	Light speckled	Kidney	14.5	6.5	47.6
S/D-66	Red speckled	Kidney	14.8	7.3	44.4
S/D-67	Yellow	Kidney	10.7	5.6	25.6

Conti….

Accession No.	Color	Shape	Length (mm)	Width (mm)	100- Seed weight (g)
S/D-68	Dark red	Cuboid	10.1	6.4	25.6
S/D-69	Dark red	Cuboid	12.3	7.7	30.8
S/D-70	Black speckled	Kidney	21.7	12.5	145.0
S/D-71	Dark red	Cuboid	12.4	6.9	28.0
S/D-72	Reddish	Cuboid	11.7	7.3	28.8
S/D-73	Cream white	Oval	12.3	8.8	42.8
S/D-74	Brownish	Oval	12.8	8.6	56.8
S/D-75	Light speckled	Oval	13.9	8.7	50.0
S/D-76	Dark red	Oval	12.2	9.1	56.0
S/D-77	Cream white	Cuboid	15.0	6.9	54.4
S/D-78	Dark red	Kidney	17.2	7.1	47.2
S/D-79	Cream white	Kidney	14.9	6.3	44.8
S/D-80	Yellow	Cuboid	14.0	7.4	41.2
S/D-81	White	Cuboid	9.0	6.1	16.0
S/D-82	Grey	Cuboid	12.0	7.6	37.0
S/D-83	Dark red	Cuboid	12.5	7.5	24.0
S/D-84	Light speckled	Oval	10.8	7.2	47.6
S/D-85	Reddish	Cuboid	13.5	8.0	28.4
S/D-86	Reddish	Cuboid	12.2	7.6	28.8
S/D-87	Brownish	Cuboid	11.7	7.1	26.8
S/D-88	Reddish	Cuboid	13.1	7.7	33.2
S/D-89	Dark red	Cuboid	12.2	7.4	31.2
S/D-90	Light speckled	Kidney	11.9	7.0	20.8
S/D-91	Light speckled	Cuboid	14.0	8.1	48.0

bean germplasm collected in this region for the successful crop improvement programme.

DIVA-GIS for diversity analysis: DIVA-GIS software version 7.5.0, free downloadable software (www.diva-gis.org) was used for the analysis of diversity in phenotypic traits coordinated with geographical coordinates. Jammu & Kashmir-India shape file was used for plotting the georeferenced points using the layer menu on the software. Point-to-grid option using 'simple' method on the "Analysis Menu" and the output variables "Diversity and Statistics" were selected for getting the output files. Under diversity, Shannon diversity index was picked and for the statistics, coefficient of variation was selected. The formula for the index taken is given below:

Shannon $H' = -\sum pi \ln pi$

ni – number of individuals in the i-th class

pi – proportional abundance of the i-th class = ni / N

Grid maps on the diversity and coefficient of variation were generated for seed traits recorded on the common bean germplasm.

RESULTS AND DISCUSSION

A total of 80 diverse accessions of *P. vulgaris* were collected from 31 remote and hilly locations across the state of Jammu and Kashmir (Table 1 and Fig. 1). A wide genetic variation was observed among collected accessions in morphological characteristics of seed color, shape and size and 100-seed weight (Table 2). Common beans are an important component in dry-land farming systems especially in high altitude areas of the state. Maize and bean farming practices are very common in these areas for maize plants provide an excellent trellis for the beans of climbing types to grow. Traditionally, common bean is grown during kharif in the hills of Himalayas. Considerable common bean variability was observed in the fields located in far flung and inaccessible areas. According to several farmers in these areas red colored beans are more prone to environmental uncertainties than the beans of other colors that is why a mixture of seed is sown in the fields here to avoid a complete crop failure and ensure a good harvest of dry beans. Crop plants rely on a broad genetic base of variation in order to adjust and adapt to changing environments. On the other hand generally uniform seed of improved early maturing bushy types is sown in the fields located in easily accessible areas of the state to produce green pods and shell beans.

Local common bean genotypes represent important genetic resource used directly by marginal farmers in Jammu and Kashmir. For hundreds of years farmers have grown these plants that were selected for their adaptation to the local agro climatic conditions and their grains are very tasty. However, during last three to four decades significant portion of land in numerous areas especially in Kashmir province has been converted to apple orchards resulting in a decline in common bean production. These areas were once known for maize-bean intercrop cultivation system. In the year 1953-54 area under fruit cultivation in the state was just 12.4 thousand hectares with the production of only about 16 thousand metric tons. At present,an area of more than 3.25 lakh hectares of land is under fruit cultivation and the fruit production is

Table 3. Descriptive statistical analysis of three quantitative characters of *P. vulgaris* germplasm collected from Jammu and Kashmir, India.

	Length (mm)	Width (mm)	100-seed weight (g)
Minimum	8.20	5.30	14.40
Maximum	21.70	12.50	145.00
Range	13.15	7.20	130.60
Mean	12.27	7.31	34.60
Standard Error	0.23	0.11	1.91
Standard Deviation	2.09	1.00	17.09
Skewness	1.22	1.68	3.70
Kurtosis	4.53	8.20	21.29

above 22 lakh metric tons. However, farmers in the farflung hilly areas of the region continue to grow traditional common bean types for self consumption and for small markets thus saving these from extinction. Prolonged dry spell and untimely rains are also said to be the reasons for a decline in common bean production. The region is now experiencing frequent unusual dry spells leading to crop failures. Common bean is generally considered susceptible as a crop to drought stress. Many farmers especially in Jammu province of the state attribute excess rains to a decline in production of pulses in general, as heavy rains damage and wash down the crop grown on sharp slopes prevalent in that region. These slopes due to fragile soils are prone to soil erosion.

Thirteen colors of bean seeds were represented in the 80 accessions with high predominance of red colored seeds in our present study (Table 2 and Fig. 2). Common bean seed color and seed shape are the most prominent indicators of genetic variability and consumer habits but seed size varies with region of domestication (Sexton *et al.*, 1997). Red colored kidney shaped and medium sized beans are preferred equally in all parts of the state while many farmers claim black colored bean seeds to be tasty and good for the stomach. Cuboid seed shape was observed to be most common in the collected germplasm. Cuboid, kidney and oval seed shapes observed were represented respectively in 61.25%, 25% and 13.75% of the 80 collected genotypes. There were significant variations in seed length, width and 100-seed weight (Table 3). Especially highly significant variations were observed in 100-seed weight among the 80 genotypes. Besides seed length and width, highest 100-seed weight of 145g was recorded in the collection S/D-70. One can rarely see plants of this accession growing in the maize-bean fields; instead fewer plants are commonly grown in kitchen gardens being used as green vegetable owing to its large fleshy green pods and much bigger seeds. Seeds of accession S/D-38 collected from a far-flung village Thakraie in Kishtwar are said to be very tasty and unlike other types of beans are believed to cause very little discomfort in the gut when consumed. Several inaccessible villages located in the Keshwan hills near this village produce these beans which are referred to as Keshwan rajma ("*rajma*" local term for common beans). Common beans are often named according to the area of their production. Shopian rajma, Badherwah rajma, Warwan rajma and Poonch rajma are famous common beans in Jammu and Kashmir named after the respective areas of their production. These are having an excellent taste. In Kashmir province farmers call some common beans types as "trepache rajma" referring to bushy type early maturing common beans. Common beans are also named according to their color, shape and size. All the three seed size classes of small, medium and large according to CIAT (Centro International de Agricultura Tropical) categorization are represented in the collected accessions. 22.5% accessions have 100-seed weight less than 25 g, 53.75% accessions have 100-seed weight between 25-40 g while 100-seed weight of more than 40 g was recorded in 23.75% of the accessions. Interestingly, similar trends in the common bean 100-seed weight have been reported in some earlier studies also (Fivawo and Msolla, 2011; Hatice and Omer, 2011).

Estimated correlation coefficient (Table 4) reveal highly significant (P<0.0001) and positive correlation between 100-seed weight and seed length and width

Table 4. Correlation coefficients among five quantitative characters of *P. vulgaris* germplasm collected from Jammu and Kashmir, India.

Trait	Pearson Correlation Coefficients, N = 80 Prob > |r| under H0: Rho = 0				
	Length (mm)	Width (mm)	SC	SH	100-Seed weight (g)
Length (mm)	1.00000	0.69947 <.0001	-0.19683 0.0801	-0.03438 0.7620	0.80566 <.0001
Width (mm)	0.69947 <.0001	1.00000	-0.23355 0.0371	0.01509 0.8943	0.78929 <.0001
SC	-0.19683 0.0801	-0.23355 0.0371	1.00000	0.16757 0.1374	-0.16794 0.1365
SH	-0.03438 0.7620	0.01509 0.8943	0.16757 0.1374	1.00000	0.22269 0.0471
100-Seed weight (g)	0.80566 <.0001	0.78929 <.0001	-0.16794 0.1365	0.22269 0.0471	1.00000

SC- Seed color; SH- Seed shape

and between seed length and seed width respectively. To understand better the overall diversity and distribution of collected common bean germplasm the data collected were analyzed by cluster analysis and DIVA-GIS software application. All the 80 *P. vulgaris* accessions were grouped in three clusters at a coefficient level of 0.3 (Semi-partial R^2 value) (Fig. 3). Largest cluster possessed 59 accessions followed by a medium cluster with 20 accessions and the least with a single accession. Collection S/D-70 is unique in its seed size and 100-seed weight, quite different from all other accessions thus forming a separate group.

Geographic information system (GIS) mapping has proven to be a powerful but simple way to visually validate location of species (Flemons *et al*., 2007). GIS mapping may be effectively used for documentation, diversity analysis, identifying gaps in collection, assessment of loss of diversity, developing new strategies for conservation, and sustainable utilization, particularly in the wake of recent international developments related to food and nutritional security. GIS mapping has been successfully used in assessing biodiversity and in identifying areas of high diversity in *Phaseolus* bean (Jones *et al*. 1997), wild potatoes (Hijmans and David, 2001), horsegram (Sunil *et al*., 2008), *Jatropha curcas* (Sunil *et al*., 2009; Shabani-mofrad *et al*., 2011), linseed (Sivaraj *et al*., 2009), blackgram (Babu Abraham *et al*., 2010), *Canavalia* fatty acids (Sivaraj *et al*., 2010), medicinal plants (Varaprasad *et al*., 2007) and agrobiodiversity (Varaprasad *et al*., 2008). In our study grid maps were generated for the diversity index for the traits of seed color, seed length and 100-seed weight using DIVA-GIS software. The highest diversity index for seed color was observed in the accessions collected from the areas falling in the districts of Budgam, Shopian, Kulgam, Ramban and Doda (Fig. 4A), whereas highest diversity index for seed length was observed in the accessions collected from areas in the three districts of Budgam, Shopian and Kulgam followed by the accessions collected from districts of Doda and Kishtwar (Fig. 4B).The highest diversity index for 100 -seed weight was observed in the accessions collected from the areas falling in the districts of Budgam, Shopian, Kulgam, Ramban and Doda (Fig. 5A). The highest diversity index for coefficient of variation for 100-seed weight was recorded in the three districts of Budgam, Shopian and Kulgam followed by parts of district Kupwara (Fig. 5B). The results indicate that diverse accessions of common bean in terms of seed size and seed weight can be sourced from the areas falling in Budgam, Shopian and Kulgam districts of the state of Jammu and Kashmir. The remarkable genetic diversity of 80 germplasm accessions collected during the course of present study, mostly from the areas known for marginal and risk prone farming systems should provide valuable alleles for adaptation to stressful environments in future breeding programmes. Such local village cultivars in any country are indispensable gene stores for developing new cultivars. Conservation of this diversity is recommended for future propagation, breeding and the investigation of the genetic relationships.

Conclusion

The remarkable genetic diversity of 80 germplasm accessions collected during the course of present study from 31 different locations mostly with marginal and risk prone farming systems across the state of Jammu & Kashmir may provide valuable alleles for adaptation to stressful environments desirable in breeding programmes. The existence of different seed shapes, sizes and colors showed the extent of common bean genetic diversity occurring in the state particularly in the districts of Budgam, Shopian and Kulgam as show by Grid maps generated through DIVA-GIS software. Conservation of this diversity is recommended for future propagation, breeding and the investigation of the genetic relationships.

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REFERENCES

Babu Abraham, V., Kamala, N., Sivaraj, N., Sunil, N., Pandravada, S. R., Vanaja, M. and Varaprasad, K. S. (2010). DIVA-GIS approaches for diversity assessment of pod characteristics in black gram (*Vigna mungo* L. Hepper). *Current Science*, 98:616-619.

Beebe, S., Skroch, P. W., Tohme, J., Duque, M. C., Pedraza, F. and Nienhuis, J.(2000). Structure of Genetic Diversity among Common Bean Landraces of Middle American Origin Based on Correspondence Analysis of RAPD. *Crop Science*, 40: 264-273.

Bitocchi, E., Nanni, L., Bellucci, E., Rossi, M., Giardini, A., Spagnoletti, Z. P., Logozzo, G., Stougaard, J., McClean, P., Attene, G. and Papa, R. (2012). Mesoamerican origin of the common bean (*Phaseolus vulgaris* L.) is revealed by sequence data. *Proceedings of the National Academy of Science*, USA, 109: 788–796.

Blair, M. W., Soler, A. and Cortés, A. J.(2012). Diversification and Population Structure in Common Beans (*Phaseolus vulgaris* L.). *PLoS ONE*, 7(11): e49488.

Camara, C. R. S., Urrea, C. A. and Schlege, V. (2013). Pinto Beans (*Phaseolus vulgaris* L.) as a Functional Food: Implications on Human Health. *Agriculture*, 3:90-111.

FAO Website(2012). Available online: http://faostat.fao.org/site/339/default.aspx(accessed on December 6th, 2012)

Fivawo, N. C. and Msolla, S. N. (2011). The diversity of common bean landraces in Tanzania. *Tanzania Journal of Natural and Applied Sciences*, 2:337-351.

Flemons, P., Guralnick, R., Krieger, J., Ranipeta, A. and Neufeld, D. (2007). A web-based GI Stool for exploring the world's biodiversity: The global biodiversity information facility mapping and analysis, Analysis Portal Application (GBIF-MAPA). *Ecological Information*, 2:49-60.

Hatice, B. and Omer, S. (2011). A sample for biodiversity in Turkey: Common bean (*Phaseolus vulgaris* L.) landraces from Artvin. *African Journal of Biotechnology*, 10:13789-13796.

Hegay, S., Geleta, M., Bryngelsson, T., Asanaliev, A., Garkava-Gustavsson, L., Hovmalm, H.P. and Ortiz, R. (2014). Genetic diversity analysis in *Phaseolus vulgaris* L. using morphological traits. *Genetic Resources and Crop Evolution*, 61:555-566.

Hijmans, R. J. and David, M. (2001). Geographic distribution of wild potato species. *American Journal of Botany*, 88: 2101-2112.

Hijmans, R., Guarino, L., Rojas, E. and Bussink, C. (2002). DIVA-GIS, version 2. A geographic information system for the analysis of biodiversity data. Manual, International Potato Center, Lima, Peru.

Jones, P. G., Beebe, S. E., Tohme, J. and Galway, N. W. (1997). The use of geographical information systems in biodiversity exploration and conservation. *Biodiversity and Conservation*, 6:947-958.

Landon, A. (2008). The "how" of the three sisters: The origins of agriculture in Mesoamerica and the human niche. *NE Anthropology*, 40:110–124.

McConnell, M., Mamidi, S., Lee, R., Chikara, S., Rossi, M., Papa, R. and McClean, P. (2010). Syntenic relationships among legumes revealed using a gene-based genetic linkage map of common bean(*Phaseolus vulgaris* L.). *Theoretical and Applied Genetics*, 121:1103-1116.

Parra-Quijano, M., Iriondo, J.M. and Torres, E. (2012). Review. Applications of ecogeography and geographic information systems in conservation and utilization of plant genetic resources. *Spanish Journal of Agricultural Research*, 10:419-429.

Sexton, P. J., Boote, K. J., White, W. J. and Peterson, C. M. (1997). Seed size and seed growth rate in relation to cotyledon cell volume and number in common bean. *Field Crops Research*, 54:163-172.

Shabanimofrad, M., Yusop, M. R., Saad, M. S., Wahab, P. E. M., Biabanikhanehkahdani, A. and Latif, M. A. (2011). Diversity of physic nut (*Jatropha curcas*) in Malaysia: application of DIVA-geographic information system and cluster analysis. *Australian Journal of Crop Science*, 5: 361-368.

Singh, S. P. (1999). Improvement of small–seeded race Mesoameriaca cultivars. In: S. P. Singh (ed) Common bean improvement in the twenty–first century. Kluwer Academic Publishers. Dordrecht. Boston,London, pp. 255-274.

Singh, S. P., Gepts, P. and Debouck, D. G. (1991). Races of common bean (*Phaseolus vulgaris*, Fabaceae). *Economic Botany*, 45:379–396.

Sivaraj, N., Sunil, N., Pandravada, S. R., Kamala, V., Vinod Kumar, Rao, B. V. S. K., Prasad, R. B. N. and Varaprasad, K. S.(2009). DIVA-GIS approaches for diversity assessment of fatty acid composition in linseed (*Linum usitatissimum* L.) germplasm collections from peninsular India. *Journal of Oilseeds Research*, 26:13-15.

Sivaraj, N., Sunil, N., Pandravada, S. R., Kamala, V., Rao, B. V.S.K., Prasad, R.B.N., Nayar, E.R., Joseph John, K., Abraham, Z. and Varaprasad, K.S. (2010). Fatty acid composition in seeds of Jack bean [*Canavalia ensiformis* (L.) DC] and Sword bean [*Canavalia gladiate* Jacq.) DC] germplasm from South India: A DIVA-GIS analysis. *Seed Technology*, 32:46-53.

Sunil, N., Sivaraj, N., Pandravada, S.R., Kamala, V., Raghuram Reddy, P. and Varaprasad, K.S. (2008). Genetic and geographical divergence in horsegram germplasm from Andhra Pradesh, India. *Plant Genetic Resources: Characterization and Utilization*, 7:84-87.

Sunil, N., Sivaraj, N., Anitha, K., Babu Abraham, Vinod Kumar, Sudhir, E., Vanaja, M. and Varaprasad, K.S. (2009). Analysis of diversity and distribution of *Jatropha curcas* L. germplasm using Geographic Information System(DIVA-GIS). *Genetic Resources and Crop Evolution*, 56:115-119.

Varaprasad, K. S., Sivaraj, N., Mohd Ismail and Pareek, S. K.(2007). GIS mapping of selected medicinal plants diversity in the Southeast Coastal Zone for effective collection and conservation. In: K. Janardhan Reddy, Bir Bahadur, B. Bhadraiah and M.L.N. Rao (eds) Advances in Medicinal Plants. Universities Press (India) Private Ltd., pp. 69-78.

Varaprasad, K. S., Sivaraj, N., Pandravada, S. R., Kamala, V. and Sunil, N.(2008). GIS mapping of agrobio-diversity in Andhra Pradesh. *Proceedings of Andhra Pradesh Akademi of Sciences. Special Issue on Plant wealth of Andhra Pradesh*. pp. 24-33.

Xu, B. and Chang, S. K. C.(2009). Total phenolic, phenolic acid, anthocyanin, flavan-3-ol, and flavonol profiles and antioxidant properties of pinto and black beans (*Phaseolus vulgaris* L.) as affected by thermal processing. *Journal of Agriculture and Food Chemistry*, 57:4754-4764.