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Collection and phenotypic characterisation of pole-type common bean (*Phaseolus vulgaris* L.) landraces from Mizoram

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ABSTRACT

Common beans are one of the many important food legumes grown in India. In the hilly regions of north-eastern India farmers mostly grow the pole-type beans by intercropping beans with maize, and in backyards and kitchen gardens. In this study, we characterized a set of 52 pole-type common bean landraces collected from the state of Mizoram for 23 agro-morphological and quality traits. Remarkable variability was observed for almost all the traits. Wide range of variability was found for the traits such as leaf length (7.5-18.0 cm), leaf breadth (6.2-12.8 cm) days to flowering (33-70 days), pods per plant (7.7-24.0), pod length (8.1-14.6 cm), pod yield per plant (61.5-182.3 g), seeds per pod (4.6-8.0), 100-seed weight (23.0-50.1 g) and crude protein content (20-33.8%). Positively significant correlation coefficients were observed between 100-seed weight and days to flowering; number of pods per plant and pod yield per plant. The patterns of morphological variation were assessed using multivariate approaches. Five morphologically distinct clusters were identified within the collected germplasm. The evolutionary grouping of the common bean landraces has been discussed considering the morphological features.

Key words: Climbing bean, genetic characterization, phenotypic diversity.

INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) has one of the longest histories of cultivated plants and is an important source of minerals and phyto-chemicals (Dutta *et al*., 3). The crop originated and was domesticated in the New World in two centres of origin (Andes and Mesoamerican), which gave rise to two major gene pools (Andean and Mesoamerican) with racial sub-divisions (Blair *et al*., 2). It is grown in different parts of the world and there are many secondary centres of diversity outside the centres of origin (Zhang *et al*., 13).

In India, common beans, popularly known as *Rajmash*, are grown in about 9.1 mha yield around 3.6 MT (FAO, 5). Information on the dissemination of common bean in India especially in the NE Himalayan region is sparse (Sofi *et al*., 12). Most possibly the common beans introduced to this part of India by English traders in early 16th century and by Chinese through Hindustan Silk Route (Joshi and Mehra, 7). The genetic diversity of Indian common beans resembles European and Chinese beans, which suggests the combination of both Andean and Mesoamerican cultivated gene pools (Angioi *et al*., 1). Mizoram is one of the eight states of NE India with a tribal population of ~95%. Diversity of pole-type common bean landraces in Mizoram is remarkable. Till date, few studies have been conducted with a limited number of landraces of Mizoram (Dutta *et al*., 4; Singh *et al*., 11). In the present study, we undertook phenotypic characterization of common bean landraces collected from Mizoram to assess the extent of variability in phenological, agro-morphological and quality traits.

MATERIALS AND METHODS

A total of 52 common bean landraces of Mizoram were used in this study. Most of the landraces were collected and maintained by the researchers at ICAR Research Complex for North Eastern Hill Region, Kolasib, Mizoram during 2008-13. The landraces were collected from six districts (Kolasib, Aizawl, Serchhip, Lunglei, Lawngtlai and Saiha) of Mizoram (Fig. 1a). The collected germplasm accessions fairly represent the pole-type common bean diversity in the state. The accessions have been sent for long-term storage at ICAR-NBPGR, New Delhi.

Data on the germplasm were recorded during June-October in 2013 and 2014. The plants were grown under screen-house conditions at Kolasib, Mizoram (24.2304° N, 92.6761° E and 722 m altitude). Two seeds per accession were sown in pots filled with 8 kg of soil (two parts of forest soil and one part of fine sand). Potting mixture properties were pH: 6.28 ± 0.17, EC: 0.984 ± 0.016, organic C (%): 1.57 ± 0.25, N (kg/ ha): 166.2 ± 9.41, P (kg/ ha): 52.5 ± 1.33, K

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(kg/ ha): 275.5 ± 19.04, Cu (mg/ kg): 1.12 ± 0.08, Zn (mg/ kg): 2.51 ± 0.11, Mn (mg/kg): 42.1 ± 1.90 and Fe (mg/ kg): 21.9 ± 0.07. A total of ten plants per accession were used to record data on vegetative morphological traits. The plants received adequate irrigation and natural photoperiod throughout the growth cycle. Range of maximum temperature, minimum temperature and RH were 33.8-35.8ºC, 23.5-28.6ºC and 81-87%, respectively during the crop growth period.

Data were recorded on 23 traits based on observations recorded on ten plants per accession following *Phaseolus vulgaris* descriptors published by IBPGR (IBPGR, 6). Data on leaf length (LL), leaf breadth (LB), days to flowering (DF), flower bud per inflorescence (FBI), nodes number at harvest (NH), number of pods per plant (PPP), pod length (PL), pod yield per plant (PYP), number of seed per pod (SPP), 100-seed weight (SW) and crude protein percent (CP) were recorded. Qualitative observations were taken on pod colour (PC), seed coat colour (SCC), colour of freshly opened flower (CFF), pod cross section (PCS), pod curvature (PCV), seed shape (SS), flower bud size (FBS), size of bracteolate (SIB), shape of bracteolate (SOB), bracteolate colour (BC), pod beak position (PBP) and pod beak orientation (PBO). The statistical parameters, *viz.* mean, standard deviation (SD), range, coefficient of variation (CV), and skewness were determined based on 2-year data of quantitative traits with completely randomised design (CRD) of experiment. Pearson's correlation coefficients (r) were calculated for the quantitative traits. The qualitative traits were subjected to frequency distribution. Z scores were used to standardize the data and then used for principal component analysis (PCA). The extracted principal components (PCs) were further used in the Ward's hierarchical clustering to assess the phenotypic diversity in common bean landraces. All the analyses were performed in SPSS.

RESULTS AND DISCUSSION

Seeds were collected mainly from the farm-stores of villages mostly located along the road side, as the terrain is very difficult (Fig. 1a). A wide range of variations were observed in the seed morphology of the collected common bean accessions of Mizoram (Fig. 1b). The descriptive statistics of range of variations recorded for eleven quantitative variables

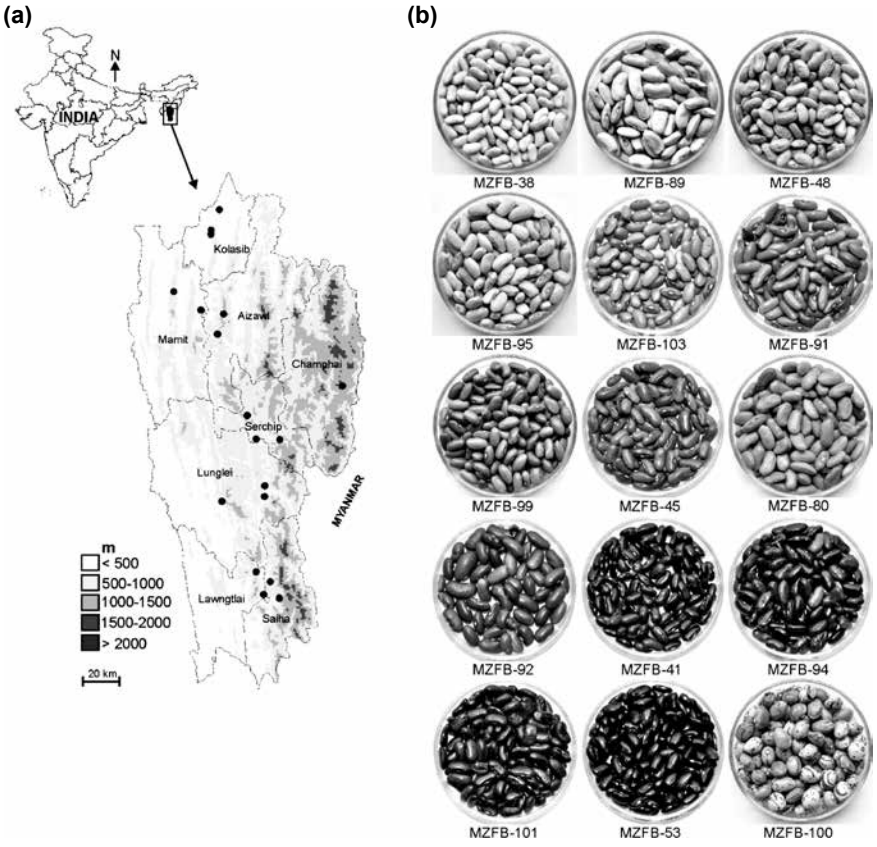

Fig. 1. Pole-type common bean landraces in Mizoram. (a) Collection sites of 52 accessions with altitude ranges indicated by gray shadings; (b) Variability in seed shape and colour in the collected germplasm.

are given in Table 1. The landraces exhibited large variations for PPP, PYP, FBI, LL and SW as appeared from the coefficient of variation values. The earliest flowering landrace was MZFB-50a (33 days) while the longest duration for flowering was observed in MZFB-80 (70 days). PPP ranged from 7.7 (IC0611109) to 24.0 (IC0611107). PYP varied from 61.5 g (IC0611109) to 182.3 g (IC0611107) with a mean value of 107.1 g. A large variation in SW was also observed. It ranged from 22.9 g (IC0611101) to 50.6 g (MZFB-100) with a mean value of 32.0 g. There was a considerable variation in crude protein content within the germplasm. The highest and the lowest CP were recorded in MZFB-81 (19.9%) and IC0611106 (33.8%), respectively. The landraces with >30% crude protein content were IC0611109, IC0611110, MZFB-99, IC0611104, MZFB-82, MZFB-107, MZFB-93 and MZFB-102. Negative skewness exhibited by traits like LB, FBI and NH indicated that most of the landraces had broader leaf, higher number of FBI and higher NH. Characterisation based on qualitative data revealed that majority of the landraces exhibited normal green PC (80.8%), brown, pale to dark SCC (69.2%), white CFF (67.3%), pear shaped PCS (55.8%), slightly curved pods (75%), cuboid seeds (51.9%), medium FBS (75%), medium SB (78.8%), intermediate SOB (61.5%), green bracteolate (63.5%), marginal PBP (59.6%) and upward PBO (40.4%) (Table 2). Considering the seed traits and growth habit, the common beans of Mizoram can be included in the Mesoamerican gene pool. Phenotypic and phonological information based on descriptors is considered as the first step for the assessment, description and classification of germplasm collections to promote the use of crop genetic resources in plant breeding programmes (Raggi *et al*., 9). The phenotypic characterization helps in deciphering the nature and magnitude of genetic divergence among the gene pools for reliable scoring during selection of potential parents for hybridization (Kumar *et al*., 8).

Pearson correlation coefficients between the quantitative agro-morphological characters are given in Table 3. There was a highly significant association ($P < 0.01$) among the traits such as LL and LB, LL and FBI, LB and FBI, DF and SW, PPP and PYP. Significant negative association associations were found between LL and DF ($P < 0.05$), LL and SW ($P < 0.01$), LB and DF ($P < 0.05$), LB and SW ($P < 0.01$), DF and FBI ($P < 0.01$), FBI and SW ($P < 0.01$). Information on the associations between yield and its components is important for improving yield through traditional plant breeding methods because it helps in choosing effective selection criteria

Hierarchical cluster analysis grouped landraces into five clusters based on the 23 agro-morphological traits (Fig. 2a). The mean values of quantitative traits of landraces falling in each cluster are presented in Table 4. The qualitative characters of the landraces in different clusters are presented in Table 5. Number of landraces in cluster varied from 9 (Cluster 1 and 2) to 13 (Cluster 5). Cluster 1 consisted of nine landraces having higher LL (14.7 cm) and PL (12.4 cm). Similarly, cluster 2 grouped nine landraces with higher LB (10.2 cm), FBI (3.6), NH (17.5) and SPP (6.4). Cluster 3 grouped 11 landraces and was characterised by the lowest mean values for all the traits. Cluster 4 comprised of 10 landraces with late flowering habit (55.6 days), bold seeds (highest 100-seed weight, 40.4 g) and maximum CP (27.3%).

Table 1. Variability in the quantitative traits in pole-type common beans.

Trait	Mean ± SD	Min.	Max.	Variance	CV (%)	Skewness
LL	12.8 ± 2.9	7.5	18.0	8.7	23.1	0.23
LB	9.3 ± 1.6	6.2	12.8	2.5	16.3	-0.25
DF	50.8 ± 5.8	33.0	70.0	34.1	11.4	0.49
FBI	2.9 ± 0.7	2.0	4.2	0.5	24.1	-0.04
NH	16.3 ± 1.7	12.6	20.0	2.9	9.8	-0.09
PPP	13.3 ± 3.9	7.7	24.0	14.9	28.6	1.04
PL	11.2 ± 1.6	8.1	14.6	2.6	14.4	0.20
PYP	107.1 ± 26.5	61.5	182.3	699.9	24.6	0.81
SPP	6.1 ± 0.8	4.6	8.0	0.7	13.1	0.50
SW	32.0 ± 6.4	22.9	50.6	40.4	19.6	1.16
CP	26.2 ± 3.3	19.9	33.8	11.1	12.5	0.25

LL = Leaf length (cm), LB = Length breadth (cm), DF = Days to flowering, FBI = Flower bud per inflorescence, NH = Nodes No. at harvest, PPP = No. of pods per plant, PL = Pod length (cm), PYP = Pod yield per plant (g), SPP = No. of seeds per pod, SW = 100-seed weight (g), CP = Crude protein content (%)

Table 2. Frequency distribution of common bean accessions for qualitative traits.

Trait	Morphological class (% landrace)				
PC	Normal green	Purple stripe on green	Dark purple	Pale red stripe on green	
	(80.8)	(5.8)	(11.5)	(1.9)	
SCC	Brown, pale to dark	Pale cream	Black	Maroon	Light brown
	(69.2)	(1.9)	(23.1)	(3.8)	(1.9)
CFF	White	Lilac	White with red stripes	Purple	
	(67.3)	(1.9)	(3.8)	(26.9)	
PCS	Very flat	Pear Shaped	Round elliptic		
	(9.6)	(55.8)	(34.6)		
PCV	Straight	Slightly curved	Curved		
	(3.8)	(75.0)	(21.2)		
SS	Oval	Cuboid	Kidney Shape	Truncate fustigate	
	(3.8)	(51.9)	(40.4)	(3.8)	
FBS	Small	Medium			
	(25.0)	(75.0)			
SB	Small	Medium			
	(21.2)	(78.8)			
SOB	Lanceolate	Intermediate	Ovate		
	(25.0)	(61.5)	(13.5)		
BC	Green	Pale violet	Dark purple		
	(63.5)	(30.8)	(5.8)		
PBP	Marginal	Non marginal			
	(59.6)	(40.4)			
PBO	Upward	Straight	Downward		
	(40.4)	(32.7)	(26.9)		

PC = Pod colour, SCC = Seed coat colour, CFF = Colour of freshly opened flower, PCS = Pod cross section, PCV = Pod curvature, SS = Seed shape, FBS = Flower bud size, SB = Size of bracteolate, SOB = Shape of bracteolate, BC = Bracteolate colour, PBP = Pod beak position, PBO = Pod beak orientation

Table 3. Correlation coefficients of quantitative traits.

	LB	DF	FBI	NH	PPP	PL	PYP	SPP	SW	CP
LL	0.87**	-0.34*	0.53**	0.09	-0.02	0.22	-0.04	0.12	-0.58**	-0.15
LB		-0.29*	0.54**	-0.05	0.08	0.15	0.09	0.05	-0.54**	-0.16
DF			-0.41**	0.05	-0.17	0.20	-0.18	-0.17	0.42**	-0.05
FBI				0.16	0.01	0.00	0.08	0.02	-0.55**	-0.01
NH					-0.03	0.05	-0.12	-0.10	-0.10	-0.01
PPP						-0.15	0.92**	0.05	-0.17	0.11
PL							-0.16	-0.10	0.15	0.12
PYP								0.02	-0.21	0.01
SPP									-0.08	0.21
SW										0.23

*$P < 0.05$ **$P < 0.01$

LL = Leaf length (cm), LB = Length breadth (cm), DF = Days to flowering, FBI = Flower bud per inflorescence, NH = Nodes No. at harvest, PPP = No. of pods per plant, PL = Pod length (cm), PYP = Pod yield per plant (g), SPP = No. of seeds per pod, SW = 100-seed weight (g), CP = Crude protein content (%)

Table 4. Comparison of cluster means for quantitative traits in common bean accessions.

Trait	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
LL	14.7 ± 2.6[a]	14.7 ± 1.8	14.1 ±2.5	9.3 ± 0.9	11.6 ± 2.4
LB	9.9 ± 1.5	10.2 ± 0.7	10.1 ± 0.9	7.4 ± 1.1	8.8 ± 1.6
DF	49.0 ± 4.5	48.9 ± 7.5	48.3 ± 2.5	55.6 ± 5.8	52.0 ± 5.6
FBI	3.4 ± 0.5	3.6 ± 0.4	3.2 ± 0.6	2.3 ± 0.5	2.6 ± 0.8
NH	17.3 ± 0.9	17.5 ± 1.8	14.8 ± 1.1	16.1 ± 1.8	16.3 ± 1.5
PPP	9.9 ± 2.2	13.7 ± 4.9	14.1 ± 3.9	12.0 ± 1.5	15.7 ± 3.6
PL	12.4 ± 1.3	10.8 ± 1.2	10.4 ± 1.2	11.4 ± 1.7	11.2 ± 1.9
PYP	81.6 ± 15.4	107.8 ± 27.5	116.3 ± 24.8	96.9 ± 11.6	124.4 ± 26.7
SPP	5.8 ± 0.6	6.4 ± 0.8	6.2 ± 0.8	6.2 ± 0.8	6.0 ± 1.1
SW	29.8 ± 3.2	27.6 ± 2.9	29.2 ± 3.1	40.4 ± 7.0	32.7 ± 5.5
CP	26.0 ± 3.9	24.9 ± 2.4	26.3 ± 4.6	27.3 ± 2.3	26.3 ± 3.0
No. of accessions	9	9	11	10	13

[a]Values represent mean ± SD

LL = Leaf length (cm), LB = Length breadth (cm), DF = Days to flowering, FBI = Flower bud per inflorescence, NH = Nodes No. at harvest, PPP = No. of pods per plant, PL = Pod length (cm), PYP = Pod yield per plant (g), SPP = No. of seeds per pod, SW = 100-seed weight (g), CP = Crude protein content (%)

Table 5. Comparison of qualitative agro-morphological traits in five clusters derived from Ward's hierarchical clustering.

Trait	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
PC	Normal green	Normal green/ Purple stripe on green	Normal green	Normal green	Normal green/ Purple stripe on green/ Dark purple/ Pale red stripe on green
SCC	Brown, pale to dark	Brown, pale to dark/ Pale cream/ Black	Brown, pale to dark/ Black	Brown, pale to dark/ Maroon/ Light brown	Brown, pale to dark/ Black/ Maroon
CFF	White/ Purple	White/ White with red stripes	White/ White with red stripes/ Purple	White	White/ Purple
PCS	Pear shaped/ Round elliptic	Very flat/ Pear Shaped/ Round elliptic	Pear Shaped/ Round elliptic	Very flat/ Pear Shaped	Very flat/ Pear Shaped/ Round elliptic
PCV	Slightly curved/ Curved	Slightly curved	Slightly curved/ Curved	Slightly curved	Straight/ Slightly curved/ Curved
SS	Cuboid/ Kidney shaped	Cuboid/ Kidney Shape/ Truncate fustigate	Oval/ Cuboid/ Kidney Shape	Oval/ Cuboid/ Kidney Shape	Cuboid/ Kidney Shape/ Truncate fustigate
FBS	Small/ Medium	Small	Small/ Medium	Medium	Small/ Medium
SB	Medium	Small/ Medium	Small/ Medium	Medium	Medium
SOB	Lanceolate/ Intermediate/ Ovate	Lanceolate/ Intermediate	Lanceolate/ Intermediate/ Ovate	Intermediate/ Ovate	Lanceolate/ Intermediate/ Ovate
BC	Green/ Pale violet	Green/ Pale violet	Green	Green	Pale violet/ Dark purple
PBP	Upward/ Straight/ Downward	Upward/ Straight/ Downward	Upward/ Straight/ Downward	Upward/ Straight/ Downward	Upward/ Straight/ Downward
PBO	Marginal/ Non marginal	Marginal/ Non marginal	Marginal/ Non marginal	Marginal/ Non marginal	Marginal/ Non marginal

PC = Pod colour, SCC = Seed coat colour, CFF = Colour of freshly opened flower, PCS = Pod cross section, PCV = Pod curvature, SS = Seed shape, FBS = Flower bud size, SB = Size of bracteolate, SOB = Shape of bracteolate, BC = Bracteolate colour, PBP = Pod beak position, PBO = Pod beak orientation

Thirteen landraces having the highest PPP (15.7) and PYP (124.4 g) included in cluster 5.

The contribution of individual landraces to the morphological grouping and the relationship between the clusters were assessed by plotting PC1 and PC2 (Fig. 2b). Cluster 1-3 formed a separate group on the biplot and was appeared to be distant from both cluster 4 and 5. Although the accessions from cluster 4 and 5 were belonged to the same major cluster (Fig. 2a), they formed two separate groups on the biplot (Fig. 2b). Both PCA and cluster analysis were found equally effective in grouping the common bean landraces based on their morphological characteristics. Nevertheless, grouping of landraces into homogenous clusters facilitates useful comparison among all possible pair of populations and provides an opportunity for bringing together gene constellation yielding desirable progenies (Rana *et al*., 10).

In conclusion, the current study serves as a baseline study for the analysis of climbing type common beans in Mizoram as well as in NE India. This study showed the predominance of Meso-American gene pools in Mizoram. The results obtained based on various genetic parameters analysed on wide range of traits, especially seed and pod traits, will help plant breeders in selecting diverse germplasm accessions for yield and its contributing

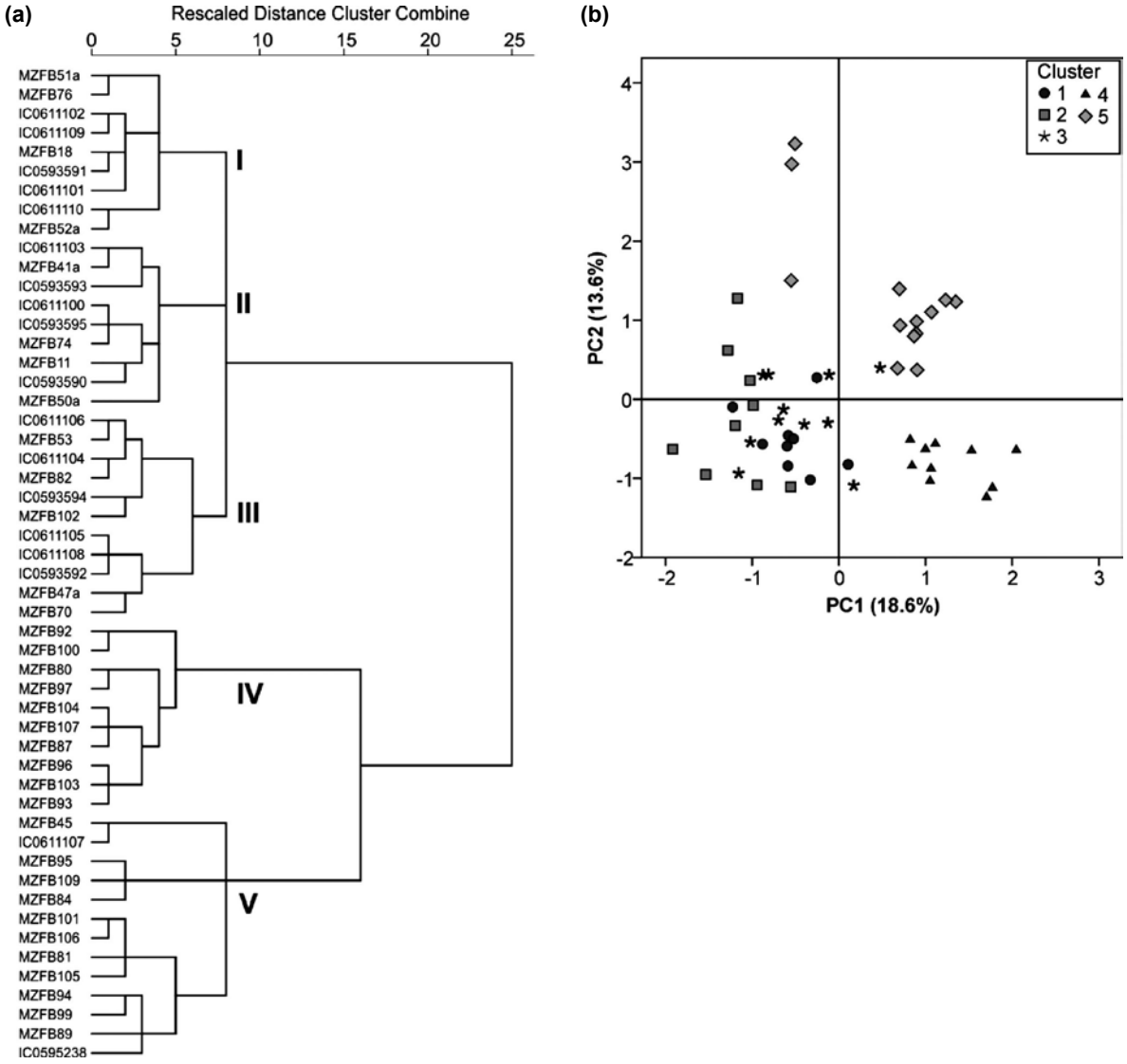

Fig. 2. Grouping of 52 pole-type common bean accessions (a) on the basis of the standardized squared Eulidean distance using Ward's hierarchical clustering method and (b) separation of the common bean landraces in PCA biplot.

traits. The collection and conservation of common bean landraces from various remote locations will safeguard these valuable genetic resources for future use.

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