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Field characterization of endemic wild *Vigna* accessions collected from biodiversity hotspots of India to identify promising genotypes for multiple agronomic and adaptive traits

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ABSTRACT

Wild *Vigna* species possess a reservoir of useful genes that have potential to be utilized in improvement of cultivated mungbean and urdbean. The level of genetic diversity in representative accessions of cultivated and wild Asiatic *Vigna* species collected from diversity-rich endemic areas of India was investigated using morphological descriptors. Data were recorded on 27 qualitative and quantitative traits in 44 wild and cultivated accessions belonging to 12 *Vigna* species grown over 2 years and analyzed to compute mean and variances for each trait. Cluster analysis following unweighted pair group method based on arithmetic mean grouped accessions into five clusters with cluster I accommodating most of the accessions. The different accessions showed variation at species level based on morphological descriptors. 3 accessions *viz.,* IC251424 and IC251425 of *V. radiata* and IC331436 of *V. trilobata* were superior for multiple traits viz., number of seeds/pod, seed quality and early maturity. Likewise for seed size, IC 298665 of *V. unguiculata* and PRR 2008-2 of *V. umbellata* were identified as promising donors while for earliness, 3 accessions of *V. trilobata* (IC 331545, IC 349701 and JAP/10-7), 1 of *V. radiata* (IC 251427) and 1 each of *V. mungo* (IC 251385) and *V. unguiculata* (IC 298665) were identified as maturing significantly early and therefore, could be used in hybridization programme for introgression of these traits. This evaluation and characterization study on endemic *Vigna* species provides useful information for improving mungbean and urdbean cultivars through recombination breeding.

Key words: Genetic diversity, Germplasm, Morphological traits, *Vigna*, Wild species.

INTRODUCTION

Vigna is a large and highly variable genus comprising more than 200 species (Pratap *et al.*, 2014). Many of these species are commercially important and are mostly grown in the warm temperate and tropical regions of the world. The major areas producing these crops are from Asia, Australia, West Indies, south and north America, and tropical and subtropical Africa. A few *Vigna* species especially mungbean [*V. radiata* (L.) Wilczek], urdbean [*V. mungo* (L.) Hepper], cowpea [*V. unguiculata* (L.) Walp], adzuki bean [*V. angularis* (Willd.) Ohwi & Ohashi], bambara groundnut [*V. subterranea* (L.) Verdn.], moth bean [*V. aconitifolia* (Jacq.)] and rice bean [*V. umbellata* (Thunb.) Ohwi & Ohashi] are cultivated in a large part in tropical Asia and also in parts of Africa. These pulses are popular in vegetarian diets. Although production statistics are not available for every individual *Vigna* species, the economically important *Vigna* crops are included with the dry beans. The annual worldwide production of the different *Vigna* species is about 23 million tons from an area of 29 million hectares [FAOSTAT 2013].

Vigna crops being suitable to a wider climate and having shorter maturity duration fit well in multiple cropping systems and therefore offer tremendous opportunities for area and production expansion in countries like India and play a crucial role in enhancing nutritional security. Nevertheless, their inherent yield potential is low as compared to other pulses and requires to be enhanced thorough recombination breeding. Efforts have been made to search for genes imparting yield traits and resistance to biotic and abiotic stresses within the cultivated species and to a limited extent among their wild relatives but success has been limited to a few diseases and insect pests; mostly where the genes are confined to the primary gene pool of the particular species (Knott and Dvorak, 1976; Stalker 1980; Ladizinsky *et al.*, 1988; Prescott and Prescott, 1986; Kumar *et al.*, 2003; Hajjar and Hodgkin 2007). The use of wild relatives as sources of new germplasm is well established in crop breeding programs in several crops, especially cereals, but the efficiency with which wild germplasm is utilized for introducing disease resistance and other agronomic characters into elite cultivars varies greatly from species to species (Bisht *et al.*, 2005a,

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2005b; Kumar *et al.,* 2011). To diversify and broaden the genetic base of cultivated germplasm, introgression of alien genes from wild species needs to be practiced in those cases where genes for some specific traits are not found in cultivated germplasm. This can be addressed through pre-breeding efforts involving particularly those wild species which carry useful alien genes for improving yield, quality and stress resistance in food legumes. Nevertheless, successful involvement of wild species in crop breeding programs requires an information on their level of genetic diversity as well as usefulness for a particular trait. A number of wild *Vigna* species are available at ICAR- Indian Institute of Pulses Research, Kanpur and have been well established in *Vigna* wide hybridization garden. The present study aimed to analyse and assess the nature and extent of genetic diversity among the 44 wild *Vigna* accessions available with us which comprised both cultivated and wild relatives using morphological traits. The ultimate objective was to identify promising genotypes for multiple agronomic and adaptive traits in *Vigna* which would be used in recombination breeding to further improve mungbean and urdbean.

MATERIALS AND METHODS

The plant materials comprised 44 accessions of 12 wild *Vigna* species (Table1). Many of these accessions were collected during two exploration trips of Western ghats in southern part of India during 2009-11 while few of them were procured form the National Bureau of Plant Genetic Resources (ICAR-NBPGR), Regional station, Thrissur, India. The accessions were grown under field conditions in the Main Research Farm of Indian Institute Pulses Research (ICAR-IIPR), Kanpur during the years 2011-12 and 2012-13. During 2011-12, these accessions were sown on 27th July, 2011 while during 2012-13 these were sown on 30th July, 2012, under normal field conditions. Each accession was sown in a plot of two rows of 4 m length, each spaced 60 cm apart with a plant-to-plant distance of 10 cm. As most of the wild accessions have variable degree of germination due to hard seed coat, scarification was done. For scarification, individual seed was held between the thumb and index finger and excision was made on its reverse side using a sharp surgical blade to avoid any damage to the embryo. Following scarification, all the seeds were incubated on moist filter paper at room temperature for 24 hours in Petri-plates followed by their direct seeding in the field. Standard agronomic practices recommended for raising mungbean crop were followed to raise a healthy crop.

Recording of observations: All the *Vigna* accessions were characterised for multiple morphological traits for two years. Data were recorded for 27 qualitative and quantitative traits (Table 3 and 4) following International Board of Plant Genetic Resources (IBPGR) descriptors (IBPGR, 1980) on five random competitive plants in each of the accessions. Data on days to flowering and maturity were recorded on plot basis. The observations were recorded at specified stages of crop growth period when the traits under study had full expression. Traits viz., growth habit, terminal leaflet shape, leaf pubescence, length of peduncle, leaf color, corolla color were recorded at the stage of 50% flowering whereas, data on pod bearing nodes, pod color, shape of ripe pod, pod length (cm), pod pubescence, constriction of pod between seeds and pod curvature were recorded at maturity. Seed size, color and shape were recorded on mature and dried seeds after harvest.

Statistical analysis: The data on various morpho-physiological traits for both the years were pooled to work out mean, range and variance. The pooled data were subjected to similarity co-efficient analysis [Jaccard, 1908] based on which a dendrogram was constructed using unweighted pair group method with arithmetic mean (UPGMA) using NTSYS pc- 2.11x [Rohlf, 2009] software. The data were also subjected to principal component analysis (PCA) using the same software.

RESULTS AND DISCUSSION

Wild and exotic germplasm offers new sources of variability hitherto not found in the cultivated species of crop plants and therefore provides additional avenues of selection for agronomic traits (Pratap *et al.* 2013). Wide hybridization has been practised in many crops to develop new recombinants with enhanced agronomic characters, quality traits and increased stress resistance. The Western ghats and the Himalayan regions of India represent a rich diversity of cultivated as well as wild and weedy types of Asiatic *Vigna* (Arora 1985, Bisht *et al.* 2005). The tremendous amount of genetic variability of *Vigna* in this region has been collected and maintained to a large extent by the partners from Indian National Agricultural Research System including ICAR-National Bureau of Plant Genetic Resources, New Delhi and ICAR-Indian Institute of pulses Research, Kanpur. Many of these accessions have been evaluated for numerous traits and crossability among different species has been worked out which is comprehensively reviewed by several workers (Singh 1990, Dana and Kamarkar, 1990, Singh *et al.,* 2003; Singh *et al.,* 2006).

For effective conservation and management of genetic resources and their efficient use in crop improvement programmes, information on genetic diversity within crop collections is useful (Mondini *et al.* 2009). 44 wild and cultivated accessions endemic to diversity rich regions of India were used to identify promising genotypes for multiple agronomic and adaptive traits. These accessions belonged to 12 different *Vigna* species, 4 of them viz., *V. radiata, V. trilobata, V. sublobata* and *V. mungo* being widely distributed. All this accessions showed variable character states and did not show any specific pattern as far as morphological characterization is concerned (Table 2 and 3).

Table 1: Details of the plant materials used in the study

Accession/Collection No.	Species	Source
IC251425	*V. radiata*	Western ghats
IC251424	*V. radiata*	Western ghats
IC251427	*V. radiata*	Western ghats
IC571775	*V. radiata*	Kumsi, Shimoga, Karnataka
IC251431	*V. radiata*	Western ghats
IC251426	*V. radiata*	Western ghats
IC251423	*V. radiata* var. *setulosa*	Western ghats
IC251419	*V. radiata* var. *setulosa*	Western ghats
IC251390	*V. mungo*	Western ghats
IC251385	*V. mungo*	Western ghats
IC251383	*V. mungo*	-
IC251386	*V. mungo*	Western ghats
IC251387	*V. mungo*	Balurghat, W.B
IC251416	*V. sublobata*	Western ghats
IC253920	*V. sublobata*	Malera, Sirohi, Rajasthan
IC247406	*V. sublobata*	Western ghats
IC277031	*V. silvestris*	Murud, Ratnagiri, Maharashtra
IC539798	*V. silvestris*	Bommanahalli, Uttar Kannad, Karnataka
IC277021	*V. silvestris*	Khopali, Raigarh,Maharashtra
IC331456	*V. trilobata*	Sariah, Bilaspur, Chhatisgarh
IC331436	*V. trilobata*	Jiban Deipur (Banpur), Khurda, Orissa
JAP/10-7	*V. trilobata*	Western ghatss
IC331454	*V. trilobata*	Ghumia, Raipur, Chhatisgarh
IC349701	*V. trilobata*	Anamalai, Coimbatore, Tamil Nadu
JAP/10-5	*V. trilobata*	Amaravathy, Coimbatore, Tamil Nadu
JAP/10-9	*V. trilobata*	Chinnar, Idukki, Kerala
IC331450	*V. hainiana*	Jaypuriaguda, Malkangiri, Orissa
IC331448	*V. hainiana*	Potreli (Korkunda), Malkangiri, Orissa
IC251376	*V. hainiana*	Kalwara, Madhya Pradesh
IC251381	*V.hainiana*	Kachari, Mandla, Madya Pradesh
IC336206	*V. dalzelliana*	Western ghats
JAP/10-51	*V. trinervia* var. *bourneae*	Nedungadappally, Kottayam, Kerala
IC210580	*V. pilosa*	Thumbormoozhi, Trissur, Kerala
IC251372	*V. glabrescens*	Haringhata, Haringhata, Madhya Pradesh
IC298665	*V. unguiculata*	Podiakala, Trivandrum, Kerala
IC251446	*V. umbellata*	IARI, New Delhi
IC251447	*V. umbellata (cultivated)*	IARI, New Delhi
IC251439	*V. umbellata (cultivated)*	Assam Agriculture University, Assam
IC251442	*V. umbellata (cultivated)*	IARI, New Delhi.
RB-5-1	*V. umbellata*	North-eastern region
PRR-2008-2	*V. umbellata*	Himalayan Region
PRR-2007-2	*V. umbellata*	Himalayan region
NSB007	*V. sublobata*	Himalayan region
TCR-279		Western ghats

Based on cluster analysis following UPGMA using quantitative data, five clusters were produced (Fig. 1, Table 4) and it was observed that the grouping of most of the genotypes was related with their pedigree relationships within these clusters. Cluster I accommodated the maximum no. of accessions (29) followed by Cluster III and IV. While cluster III had 9 accessions of different species including *V. mungo, V. silvestris, V. tilobata, V. hainiana, V. dalzelliana* and *V. glabrescens,* cluster IV accommodated 4 accessions, all of *V. umbellata* which was earlier amply justified by genotypic data also, all these accessions were grouped in population group 3 (Pratap *et al.*, 2015). Cluster II and Cluster V comprised of a single genotype each (PRR-2008-2 of *V. umbellata* and IC 298665 of *V. unguiculata*) which shows their acute deviation for many morphological traits as compared to other *Vigna* genotypes. Interestingly, only one genotype of *V. unguiculata* was used in this study which was clustered separately and therefore may be justified for separate clustering on the basis of acute diversion of morphological features of this species form other species. surprisingly separate grouping of *V. umbellata* accession PRR

Table 2: Field characterization results of wild *Vigna* accessions for 15 qualitative traits

Accession	Growth habit	Terminal leaflet shape	Leaf pubescence	Leaf color	Leaf senescence	1st Pod bearing node	Corolla color	Pod color at maturity	Shape of ripe pod	Pod pube-scence	Constriction of pod between seeds	Pod curvature	Seed color	Seed shape	Seed size
IC251425	2	1	1	2	1	6	3	3	2	5	1	1	3	2	2
IC251424	1	2	1	3	1	5	3	4	2	5	1	1	4	2	3
IC251416	3	2	1	2	1	6	3	4	2	9	0	1	5	2	2
IC251390	2	4	1	2	1	6	2	4	2	9	0	1	7	2	3
IC 251446	2	6	1	1	1	5	2	2	1	1	0	2	7	3	3
IC 251423	2	5	2	3	1	4	3	4	2	5	0	1	5	2	1
IC 251427	1	2	2	3	5	6	1	4	1	5	0	2	4	2	2
IC 251419	3	2	2	1	1	5	1	3	2	5	0	1	5	2	1
IC 277031	3	1	2	1	5	6	1	3	2	5	0	1	5	2	1
IC 331456	3	7	1	2	1	6	3	4	1	5	0	1	5	2	1
IC 539798	3	1	2	4	1	7	1	2	1	1	0	1	5	2	1
IC 331450	3	5	2	2	1	5	1	3	1	1	0	1	5	3	1
IC 331436	3	7	1	2	1	4	1	4	1	5	0	1	5	2	2
IC 331448	3	2	2	1	1	7	3	4	1	5	0	1	5	2	1
IC 331454	3	7	1	3	5	4	1	4	1	5	0	1	5	2	1
IC 298665	2	4	2	3	5	7	3	2	1	1	1	2	5	3	3
IC 251376	3	1	2	1	1	5	1	2	1	1	1	1	7	2	1
IC 251372	2	2	2	3	1	4	3	2	2	1	1	1	7	2	3
IC 251385	3	2	2	3	1	6	2	2	2	1	0	1	4	2	3
IC 349701	3	7	1	2	1	7	1	4	1	1	0	1	5	2	1
IC 210580	3	4	2	2	1	8	1	4	2	5	0	1	5	3	3
IC 251447	2	6	2	3	1	6	3	4	1	1	0	2	6	3	3
IC 251383	3	2	2	3	5	6	2	3	2	9	0	1	5	2	3
IC 251381	3	1	1	3	1	4	3	4	2	1	0	1	7	2	1
TCR-279	3	6	2	1	1	4	3	4	2	1	0	1	5	2	2
IC 251386	1	2	2	3	1	5	2	2	2	9	0	1	5	2	3
IC 336206	3	2	2	1	1	5	1	2	1	1	0	1	5	2	1
IC 253920	3	7	2	3	1	7	3	3	2	1	1	1	5	2	2
IC 247406	3	1	2	2	1	7	3	4	1	5	0	1	5	2	1
IC 251387	2	2	2	2	5	4	2	2	2	9	0	1	7	2	3
JAP/10-07	3	2	2	2	5	4	2	4	1	5	0	1	5	2	1
JAP/10-5	3	6	2	2	5	6	2	4	1	5	0	1	5	2	1
JAP/10-9	3	6	2	2	5	6	2	4	1	5	0	1	5	3	1
JAP/10-51	3	6	2	2	1	5	2	4	1	5	0	1	5	2	2
IC571775	1	1	2	3	1	8	1	3	2	9	1	2	4	2	3
IC 251439	3	6	1	1	1	5	1	2	1	1	1	2	7	3	3
IC 251431	2	1	2	2	1	7	3	4	1	5	1	1	7	2	3
IC 251442	2	6	1	2	1	6	2	4	1	1	0	1	7	3	3
IC 251426	2	1	2	2	1	6	3	4	2	5	1	1	4	2	2
IC 277021	3	2	2	1	1	7	1	3	2	9	0	1	5	2	2
RB-5-1	3	4	1	2	1	7	2	2	1	1	0	1	6	3	3
PRR-2008-2	2	4	1	2	1	5	2	2	1	1	0	1	5	3	3
NSB007	2	7	2	2	1	4	2	4	1	1	0	1	6	2	2
PRR-2007-2	2	7	1	2	1	4	2	2	1	1	0	1	7	3	3

Growth habit (1: Erect; 2- semi-erect; 3 -Spreading) Terminal Leaflet shape (1-Deltoid; 2-Ovate; 4-Ovate-lanceolate; 5-Cuneate; 6-Lobed; 7-Other); Leaf Pubescence (1-Glabrous; 2-Pubescent); Leaf color (1-Light green 2-green 3-Dark green); Leaf senescence (1-Not visibly senescent; 5-Intermediate); Corolla color: (1-Light yellow; 2-Deep yellow; 3-Greenish yellow); Pod color of mature stage (2-Tan; 3-Brown; 4-Black); Shape of ripe pod: (1-Semi-flat; 2-Round); Pod pubescence: (1-Glabrous; 5-Intermediate; 9-Heavily pubescent); Constriction of pod between seeds: (1-Present; 0-Absent); Pod curvature: (1-Least curved; 2-Medium); Seed color: (3-Light green; 4-Dark green; 5-Brown; 6-Mixed; 7-Other); Seed shape: (2-Oval; 3-Drum shaped); Seed size: (1-Small; 2-Medium; 3-Large)

Table 3: Field characterization results of wild *Vigna* accessions for 12 quantitative traits

Accession No.	Days to 1st flowering	Days to 1st podding	Length of peduncle (cm)	Terminal leaflet length(cm)	Petiole length (cm)	Days to maturity	*PH at 30DAS	Days to 1st branching	PH at 45DAS	**Chl C at 30 DAS	Pod length (cm)	Number of seed /pod
IC251425	31	35	1	7	11	51	14	32	42	51	7	11
IC251424	36	41	3	5	6	43	22	32	42	32	5	8
IC251416	25	29	1	1	3	55	6	39	19	23	3	4
IC251390	36	41	2	6	6	59	14	31	23	43	4	6
IC 251446	55	58	3	8	16	115	22	36	108	38	8	6
IC 251423	33	39	2	5	9	60	5	39	12	51	5	4
IC 251427	25	29	1	4	6	42	14	36	32	35	6	8
IC 251419	49	55	3	8	11	68	5	39	16	33	3	7
IC 277031	82	87	3	3	4	105	4	55	7	39	4	5
IC 331456	29	31	3	3	10	44	5	36	10	39	4	7
IC 539798	88	97	1	4	7	113	3	55	6	21	4	6
IC 331450	51	55	3	4	3	121	4	37	11	39	4	7
IC 331436	21	24	3	3	12	51	3	39	11	44	4	12
IC 331448	78	83	1	7	9	142	4	58	6	34	4	9
IC 331454	29	31	2	3	11	44	6	36	12	46	4	10
IC 298665	45	49	3	5	5	48	94	31	172	38	12	9
IC 251376	50	54	2	9	7	71	5	44	31	35	4	6
IC 251372	106	110	1	11	19	135	14	37	41	38	8	9
IC 251385	60	64	1	5	8	96	13	36	26	39	4	7
IC 349701	28	32	2	4	7	44	3	41	7	38	4	9
IC 210580	26	31	2	3	7	49	3	26	7	46	4	9
IC 251447	70	73	1	9	18	115	15	39	34	38	7	7
IC 251383	66	69	1	5	8	112	16	36	22	49	4	6
IC 251381	48	52	1	9	7	66	5	39	20	33	4	10
TCR-279	38	43	2	6	7	86	8	39	19	35	4	7
IC 251386	51	55	1	6	10	69	20	36	37	37	5	6
IC 336206	114	119	1	2	5	141	3	64	4	31	4	6
IC 253920	51	57	1	2	5	85	10	39	20	40	5	6
IC 247406	40	45	3	8	9	69	8	36	24	45	4	12
IC 251387	36	41	1	7	9	57	15	31	27	44	4	6
JAP/10-07	73	73	3	4	13	88	3	36	6	37	4	7
JAP/10-5	54	59	2	4	17	64	3	39	9	49	4	6
JAP/10-9	54	59	1	4	16	63	3	39	7	51	4	6
JAP/10-51	40	45	2	9	8	64	17	36	36	44	5	6
IC571775	35	39	1	9	10	58	23	32	50	50	6	12
IC 251439	96	99	3	10	26	139	23	36	100	31	8	7
IC 251431	31	37	2	10	14	59	16	39	51	48	7	7
IC 251442	100	104	1	10	23	139	19	36	99	35	8	5
IC 251426	31	35	2	4	6	54	12	39	25	32	6	10
IC 277021	45	52	3	7	9	55	6	36	19	39	4	11
RB-5-1	72	76	3	9	17	128	37	36	97	31	10	6
PRR-2008-2	40	43	3	9	13	70	31	36	95	38	10	7
NSB007	22	26	2	5	13	52	7	39	28	38	6	13
PRR-2007-2	44	47	3	7	11	65	23	36	58	28	10	7
Mean	50.77	55.07	1.95	5.98	10.25	78.50	13.32	38.39	34.73	38.75	5.41	7.61
S.D.	23.84	23.96	0.86	2.61	5.13	32.05	14.98	7.10	35.26	7.19	2.15	2.23
Range	21-114	24-119	1-3	1-11	3-26	42-142	3-94	26-64	4-172	21-51	3-12	9

*PH=plant height and DAS=days after sowing; **Chl C=chlrophyll content

2008-2 is contrary to its clustering in population group 3 (Pratap *et al.* 2015) on the basis of genotyping data and suggests high influence of environment on expression of phenotypic traits which led to its separate grouping. The acute diversion in grouping of accessions of same *Vigna* species has been suggested earlier by Bisht *et al.* (2005), Yimran *et al.* (2009) and Pratap *et al.*, (2015).

In general it was observed that all the *Vigna* accessions differed in various plant, flower and seed characters as characterization on the basis of morphological data revealed presence of at least 2 distinct groups for each character state, sometimes even upto 5 groups such as in case of seed colour. Several earlier workers have also described clear cut distinct groups for various morphological character states in *Vigna* (Lawn 1995, Tomoka *et al.*, 2000, 2003, Bisht *et al.*, 2005, Pratap *et al.*, 2015). Among the species in the mungbean group viz., *V. hainiana*, *V. trilobata*, *V. mungo* var. *silvestris*, *V. radiata* var. *setulosa* and *V. radiata* var. *sublobata* accessions showed greater homology in growth habit. Most of the wild accessions under study were characterized as spreading types, except the 3 accessions of *V. radiata* (IC251425, IC251427, IC571775) and one accession each of *V. hainiana* (IC251376) and *V. mungo* (IC251386), which were of erect type. From agronomical point of view, erect plant types are more preferred since these help in greater light penetration in the canopy and also favour mechanical harvesting. Therefore, it is evident that for imparting erect plant types, cultivated *Vigna* accessions will be more useful as donors in improvement programmes.

While there was greater homology for growth habit, all accessions differed significantly for leaf traits. 4 accessions of *V. radiata* (IC251426, IC251425, IC25143 and IC571775), 2 accessions each of *V. silvestris* (IC277031, IC539798) and *V. hainiana* (IC251376, IC251381), and 1 accession of *V. sublobata* (IC247406) were observed to have deltoid terminal leaf shape whereas acute type terminal leaflet shape was observed only in 1 accession of *V. pilosa* (IC210580). Lobed and ovate leaflet shape was observed for remaining wild accessions. Genotypes with unique leaflet shape act as a morphological marker during breeding cycles and even during seed production can be used to maintain the genetic purity. Leaf pubescence was absent in 5 accessions of *V. umbellata* (IC251446, IC251439, IC251442, RB-5-1, PRR -2008-2), 3 of *V. trilobata* (IC331436, IC331454, IC349701), 2 accessions each of *V. radiata*

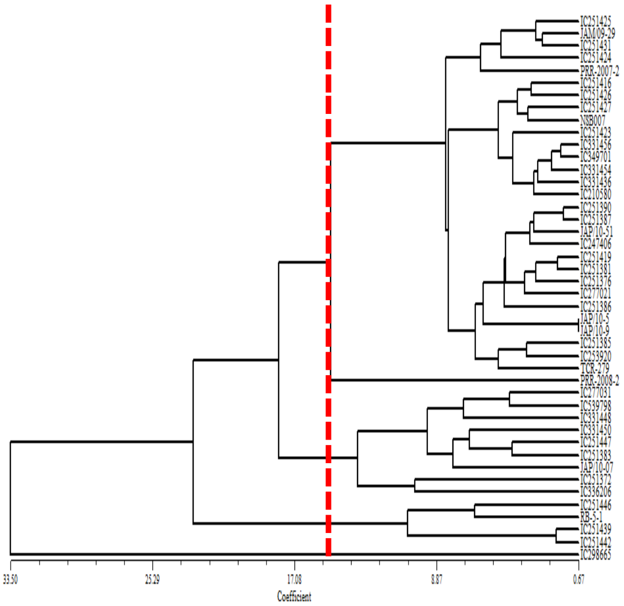

Fig-1: Dendrogram showing grouping of test genotypes based on UPGMA analysis

(IC251425, IC251424), V. *mungo* (IC251390, IC251385) and *V. hainiana* (IC251381, IC331448) and 1 accession each of *V. sublobata* (IC251416) and *V. glabrescens* (IC251372).

Leaf color varied from light green to dark green in the different accessions studied. Most of the accessions in present study were medium green in color except the accessions belonging to *V. hainiana* (IC251376), *V. radiata* (IC251425, IC251427, IC571775) *V. trilobata* (IC331454), *V. unguiculata* (IC298665), *V. glabrescens* (IC251372), *V. umbellata* (IC251447), *V. mungo* (IC251385, IC251383, IC251386) and *V. sublobata* (IC253920) which had dark green leaves. Leaf senescence was observed to be another important physiological character with sufficient genetic variability. Few accessions of *V. radiata* (IC251427), *V. silvestris* (IC277031), *V. trilobata* (IC331454, JAP/10-7, JAP/10-5, JAP/10-9), *V. unguiculata* (IC298665 and *V. mungo* (IC251383, IC251387) had intermediate leaf senescence and remaining were non senescent.

On the basis of peduncle length, the *Vigna* accessions were classified into three groups *viz.*, short (<14cm), medium (14-18), and long (>18cm) peduncle. Corolla color also varied in various shades of yellow from

Table 4: UPGMA clustering of wild *Vigna* accessions

Clusters	Accession No.
Cluster I	IC251425, IC571775, IC251431, IC251424, PRR-2007-2, IC251416, IC251426, IC251427, NSB007, IC251423, IC331456, IC349701, IC331454, IC331436, IC210580, IC251390, IC251387, JAP/10-51, IC247406, IC251419, IC251381, IC251376, IC277021, IC251386, JAP/10-5, JAP/10-9, IC251385, IC253920, TCR-279
Cluster II	PRR-2008-2
Cluster III	IC277031, IC539798, IC331448, IC331450, IC251447, IC251383, JAP/10-07, IC251372, IC336206
Cluster IV	IC251446, RB5-1, IC251439, IC251442
Cluster V	IC298665

Table 5: Field characterization results summarized on the basis of mean values.

Morphological characteristics	Character state	Accessions
Growth habit	Erect	IC251424, IC251427, IC251386, J AM/09-29
	Semi-erect	IC251425, IC251390, IC251446, IC251442, IC251423, IC298665, IC251372, IC251387, IC251431, IC251426,PRR-2008-2, NSB007, PRR-2007-2, IC251447
	Spreading	Rest of the accessions
Terminal leaflet shape	Deltoid	IC251425, IC277031, IC539798, IC251376, IC251381, IC247406, IC251431, IC251426, JAM/09-29
	Ovate	IC251424, IC251416, IC251427, IC251419, IC331448, IC251372, IC251385, IC251383, IC251386, IC336206, IC251387, JAP/10-7, IC277021
	Acute	IC210580
	Ovate-lanceolate	IC251390, IC298665, RB-5-1, PRR-2008-2
	Cuneate	IC251423, IC331450
	Lobed	IC251446, IC251447, 279, IC251439, IC251442, JAP/10-5, JAP/10-9, JAP/10-51
	Others	IC331456, IC331436, IC331454, IC349701, IC253920, NSB007, PRR-2007-2
Leaf pubescence	Glabrous	IC251425, IC251424, IC251416, IC251390, IC251446, IC331456, IC331436, IC331454, IC349701, IC251381, IC251439, IC251442, RB-5-1, PRR-2008-2
	Pubescent	Rest of the accessions
Leaf color	Light green	IC251446, IC251419, IC277031, IC331448, IC251376, 279, IC336206, IC251439
	Green	IC251416, IC251390, IC331456, IC331450, IC331436, IC349701, IC210580, IC247406, IC251387, JAP/10-7, IC25143, IC251442, JAP/10-5, JAP/10-9, JAP/10-51, JAP/10-5, JAP/ 10-9, JAP/10-51, RB-5-1, PRR-2008-2, NSB007
	Dark green	IC251424, IC251427, IC331454, IC298665, IC251372, IC251385, IC251447, IC251383, IC251386, IC253920, JAM/09-29
	Others	IC539798
Leaf senescence	Conspicuously concurrent	Nil
	Intermediate	IC251427, IC277031, IC331454, IC298665, IC251383, IC25138, JAP/10-, JAP/10-5, JAP/10-9
	Not visibly senescent	Rest of the accessions
I[st] pod bearing node	4	IC251423, IC331436, IC331454, IC251372, IC251381, 279, IC25138, JAP/10-7, NSB007, PRR-2007-2
	5	IC251424, IC251386, IC251419, IC331450, IC251376, IC251386, IC336206, IC251439, PRR-2008-2, JAP/10-51
	6	IC251425, IC251416, IC251390, IC251427, IC277031, IC251385, IC251447, IC251383, JAP/10-5, JAP/10-9, IC251442, IC251426, IC331456
	7	IC539798, IC331448, IC298665,-, IC349701, IC253920, IC247406, IC251431, IC277021, RB-5-1
	8	IC210580, JAM/09-29
Length of peduncle	Short (<14cm)	IC251425, IC251416, IC251427, IC539798, IC331448, IC251372, IC251385, IC251447, IC251383, IC251381, IC251386, IC336206, IC253920, IC251387, IC349699, IC256158, IC251442, JAP/10-9, JAM/09-29
	Medium (14-18cm)	IC251390, IC251423, IC331454, IC251376, IC349701, IC210580,TCR 279, IC251431, IC251426, NSB007, JAP/10-5, JAP/10-51
	Long (>18cm)	IC251424, IC251446, IC251419, IC277031, IC331456, IC331450, IC331436, IC298665, IC247406, JAP/10-7, IC251439, IC277021, RB-5-1, PRR-2008-2, PRR-2007-2
Corolla color	Light yellow	IC251427, IC251419, IC277031, IC539798, IC331450, IC331436, IC331454, IC251376, IC349701, IC210580, IC336206, IC251439, IC277021, 349699, 256158, JAM/09-29
	Deep yellow	IC251390, IC251446, IC331456, IC251385, IC251383, IC251386,IC251387, JAP/10-7, JAP/ 10-5, JAP/10-9, JAP/10-51, IC251442, RB-5-1, NSB007, PRR-2008-2, PRR-2007-2
	Greenish yellow	IC251425, 72, IC251416, IC251423, IC331448, IC298665, IC251372, IC251447, IC251381, 279, IC253920, IC247406, IC251431, IC251426
Pod color at mature stage	Straw	Nil
	Tan	IC251446, IC539798, IC298665, IC251376, IC251372, IC251385, IC251386, IC336206, IC251387, IC251439, RB-5-1, PRR-2008-2, PRR-2007-2
	Brown	IC251425, IC251419, IC277031, IC331450 , IC251383, IC253920, IC277021, JAM/09-29

continue Table-5.....

	Black	Rest of the accessions
Shape of ripe pod	Semi-flat	IC251446, IC251427, IC331456, IC539798, IC331450, IC331436, IC331448, IC331454, IC298665, IC251376, IC349701, IC251447, IC336206, IC247406, JAP/10-7,IC251439, IC251431, IC251442, JAP/10-5, JAP/10-9, JAP/10-51, RB-5-1, PRR-2008-2, NSB007, PRR-2007-2
	Round	Rest of the accessions
Pod length (cm)	< 5cm	IC251424, IC251416, IC251390, IC251423, IC251419, IC277031, IC331456, IC539798, IC331450, IC331436, IC331448, IC331454, IC251376, IC251385, IC349701, IC210580, IC251383, IC251381, 279, IC251386, IC336206, IC253920, IC247406, IC251387, JAP/10-7, IC277021, 256158, JAP/10-5, JAP/10-9
	5-7cm	IC251427, IC251447, IC251431, IC251426, JAP/10-51, JAM/09-29, NSB007
	>7cm	IC251425, IC251446, IC298665, IC251372, IC251439, IC251442, RB-5-1, PRR-2008-2, PRR-2007-2
Pod pubescence	Glabrous	IC251446, IC539798, IC331450, IC298665, IC251376, IC251372, IC251385, IC349701, IC251447, IC251381, 279, IC336206, IC253920, IC251439, IC251442, RB-5-1, PRR-2008-2, NSB007, PRR-2007-2
	Intermediate	IC251425,72, IC251423, IC251427, IC251419, IC277031,IC210580, IC331456, IC331436, IC331448, IC331454, IC247406, JAP/10-7, IC251431, IC251426, JAP/10-5, JAP/10-9, JAP/10-51
	Heavily pubescent	IC251416, IC251390, IC251383, IC251386, IC251387, IC277021, JAM/09-29
Constriction of pod between seeds	Present	IC251425, IC251424, IC298665, IC251376, IC251372, IC253920, 349699, 256158, IC251439, IC251431, IC251426, JAM/09-29
	Absent	Rest of the accessions
Pod curvature	Medium	IC251446, IC251427, IC298665, IC251447, IC251439, JAM/09-29
	Least curved	Rest of the accessions
Seed color	Light green	IC251425
	Dark green	IC251424, IC251427, IC251385, 256158, IC251426, JAM/09-29
	Brown	IC251416, IC251423, IC251419, IC277031, IC331456, IC539798, IC331450, IC331436, IC331448, IC331454, IC298665, IC349701, IC210580, IC251383, 279, IC251386, IC336206, IC253920, IC247406, JAP/10-7, IC277021, JAP/10-5, JAP/10-9, JAP/10-51, PRR-2008-2
	Mixed	IC251447, RB-5-1, NSB007
	Other	IC251390, IC251446, IC251376, IC251372, IC251381, IC251387, IC251439, IC251431, IC251442, PRR-2007-2
Seed size	Small	IC251423, IC251419, IC277031, IC331456, IC539798, IC331450, IC331448, IC331454, IC251376, IC349701, IC251381, IC336206, IC247406, JAP/10-7, JAP/10-5, JAP/10-9
	Medium	IC251425, IC251424, IC251390, IC251381115, IC251416, IC251383, IC251386, IC251387, IC251427, IC331436, IC251431, TCR-279, IC253920, IC251426, IC277021, NSB007, JAP/10-51
	Large	IC251446, IC298665, IC251372, IC210580, IC251447, 349699, IC256158, IC251439, IC251442, JAM/09-29, RB-5-1, PRR-2008-2, PRR-2007-2
Seed shape	Drum	IC251446, IC331450, IC298665, IC210580, IC251447, IC251439, IC251442, JAP/10-9, RB-5-1, PRR-2008-2, PRR-2007-2
	Oval	Rest of the accessions
Terminal Leaflet Length	Medium (10-30cm)	IC251439, IC251431, IC251442, IC251372
	Large (>13cm)	-
	Small (<10cm)	Rest of the accessions
Petiole length	Large (>18cm)	IC251439, IC251442
	Medium (12-18cm)	IC251446, IC251372, IC251447, JAP/10-07, JAP/10-5, JAP/10-9, IC251431, RB-5-1, PRR-2008-2, NSB007, PRR-2007-2
	Short (<12cm)	Rest of the accessions

light to dark in the accessions studied. Accessions of *V. umbellata* (IC251439), *V. radiata* (IC251427, IC571775), *V. radiata* var. *setulosa* (IC251419), *V. silvestris* (IC277031, IC539798, IC277021) *V. hainiana* (IC331450, IC251376), *V. trilobata* (IC331436, IC331454, IC349701) and *V. dalzelliana* (IC336206) had light yellow flower colour while most of the other accessions were either dark yellow or greenish yellow in color. Bisht *et al.* (2005) also reported that all the species in subgenus Ceratotropis had flower colour in various shades of yellow. Coloration of pod is another character which is quite useful and varietal differentiation. The color of pod was observed as tan, brown and black. It was observed as black in most of the accessions under study except a few accessions of *V. sublobata* (IC253920), *V. radiata* (IC251425, IC571775) *V. radiata* var. *setulosa* (IC251419), *V. silvestris* (IC277031, IC277021)

V. hainiana (IC331450) and *V. mungo* (IC251383) where it was brown. Pod colour acts as a morphological marker and may be deployed in quality seed production programmes at maturity stage to monitor the mixture of other varieties.

Shapes of ripe pod of wild accessions were classified into semi-flat and round. Few accessions of *V. sublobata* (IC251416, IC253920), *V. mungo* (IC251390, IC251385, IC251383, IC251386, IC251387), *V. silvestris* (IC277031, IC277021), *V. glabrescens* (IC251372), *V. pilosa* (IC210580), *V .radiata* (IC251424, IC251425, IC251426, IC 571775) *V. radiata* var. *setulosa* IC251423, IC251419), *V. hainiana* (IC251381) and TCR-279 was round in shape and remaining were semi-flat. Shape of ripe pod directly related with the shape of seed. Pod length was observed to have limited variability in this study. Most of the accessions in wild *Vigna* were small (<4cm) in size except few accessions of *V .radiata* (IC251425),*V. umbellata* (IC251446, IC251442, RB-5-1, PRR-2008-2, PRR-2007-2, IC251439) *V. unguiculata* (11.5cm) (IC298665) and *V. glabrescens* (8.2cm) (IC251372) which were large (>8cm) in size. Curvature of pod was minimal in all accessions except in *V. umbellata* (IC251446, IC251447, IC251439), *V. radiata* (IC251427, IC571775) and *V. unguiculata* (IC298665).

Seed colour, size and shape are three important seed quality parameters in mungbean which decide consumer acceptance of a particular variety. Varieties with shining green and oval grains with medium size (3-3.8 g/100-seed weight) are more preferred over dull, brown or black and drum shaped mungbean grains. On the basis of seed color, accessions under study were classified into light green, dark green and brown. Most of the accessions were brown in color except 5 accessions of *V. radiata* (IC251424, IC251425, IC251427, IC251426, IC571775) and 1accession of *V. mungo* (IC251385) which were dark green in color. Likewise, seed shape was also classified into two groups i.e. oval and drum. All accessions were oval in shape except *V. trilobata* (JAP/10-9), *V. umbellata* (IC251446, IC251447, IC251439, IC251442, RB-5-1, PRR-2008-2, PRR-2007-2), *V. hainiana* (IC331450), *V. pilosa* (IC210580) and *V. unguiculata* (IC298665) which were drum shaped. On the basis of seed size, the accessions were classified into three groups *viz.*, small, medium and large seeded. Most of the accessions belonged to small and medium seeded category. Large seed size was observed in accessions of *V. pilosa* (IC210580), *V. radiata* (IC571775), *V. umbellata* (IC251446, IC251447, IC251439, IC251442, RB-5-1, PRR-2008-2, PRR-2007-2), *V. unguiculata* (IC298665) and *V. glabrescens* (IC251372).

Among the quantitative traits days to 1st flower and days to maturity were the most important traits of observation. Great variation was observed for both these traits as days to Ist flower ranged between 21-114 days while days to maturity ranged between 42-142 days. Interestingly, 7 accessions viz., 3 of *V. trilobata* (IC 331545, IC 349701 and JAP/10-7), 2 of *V. radiata* (IC 251424 and IC 251427) and 1 each of *V. mungo* (IC 251385) and *V. unguiculata* (IC 298665) matured in < 50 days. Therefore, these accessions hold great promise to be utilized as donors for developing early maturing genotypes in mungbean and urdbean. Short-duration mungbean can avoid the adverse effects of terminal heat stress during summer season and adverse effect of untimely rains at harvest time during rainy season (Pratap *et al.*, 2014) and therefore can be tremendously useful in expanding mungbean area in northern and central part of India during summer season (Pratap *et al.*, 2013). Number of seeds/pod is another trait which is targeted directly by a breeder. There was a great variability for this trait also (4-13 seeds in different accessions) and 4 accessions viz., IC 571775 of *V. radiata*, IC 247406 of *V. sublobata*, IC 331436 of *V. trilobata* and NSB 007 recorded >12 seeds/pod and therefore can be used in hybridization programme to transfer this trait.

In conclusion, a large amount of variability was observed among different wild and cultivated *Vigna* species in this study. Based upon morphological evaluation, 3 accessions viz., IC251424 and IC251425 of *V. radiata* and IC331436 of *V. trilobata* were identified as superior donors for multiple traits such as number of seeds/pod, seed quality and early maturity. For large seed size, IC 298665 of *V. unguiculata* and PRR 2008-2 of *V. umbellata* were identified as promising donors while for earliness, 3 of *V. trilobata* (IC 331545, IC 349701 and JAP/10-7), 1 of *V. radiata* (IC 251427) and 1 each of *V. mungo* (IC 251385) and *V. unguiculata* (IC 298665) could be used in hybridization programme. Therefore, characterization and evaluation of variation among *Vigna* species in this study would be of great significance for designing breeding programme, both for qualitative and quantitative improvement and the identified *Vigna* accessions could be used in hybridization programme for improvement of elite mungbean and urdbean cultivars.

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