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GERMPLASM COLLECTION AND MORPHOLOGICAL CHARACTERIZATION OF DIVERSITY AMONG WILD *VIGNA* FROM WESTERN GHATS AND NORTHERN KARNATAKA IN INDIA

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Abstract

The wild Vigna is one of the important legumes known for their potential nutritional values and the field survey was conducted in areas of Western Ghats of Karnataka, Kerala and northern Karnataka. Total of sixteen accessions were collected during the period from 2015 to 2017. Thirteen quantitative and seven qualitative characters of morphometric analysis were considered to assess specific variations. The largest variations found in peduncle length and least in seed width of covariance 54.76 and 0.07 with considerable ranges 18.27 and 1.03 with respectively. The correlation coefficient of seed set percentage was positively correlated with plant height (0.407), terminal leaflet length (0.359), terminal leaflet width (0.295), pod length (0.320), seed length (0.289), seed width (0.080), seed weight (0.188), number of seeds per pod (0.445) and number of locules per pod (0.181). First two principal components (PC) has influenced with 82.00% of the total variations, the PC-1 alone accounted for 54.00% and it is directly influenced by traits of the number of flowers per raceme (0.334) and numbers of pods per peduncle (0.321). In factor analysis, all the four factors accounted for 90.00% of total variations, the first factor alone exhibit 42.00% was strongly associated with the peduncle length (0.428), the number of flower per raceme (-0.692), the number of pod per peduncle (-0.864), pod length (0.928) seed length (0.946), seed width (0.713) and the seed weight (0.972). In dendrogram, structure at 6% point the two sub-clusters (G3 and G4) exhibit closely relatives of V. dalzelliana var. dalzelliana (Kuntze) Verdc., of four accessions (DalKrt, DalAgb, DalKun and DalJof) and three accessions (DalMkf, DalBsg and DalRnp). Furthermore, at the point 19% stage of the main cluster and classified very distantly in two separate groups mainly V. stipulacea Kuntze of four accessions (StpKnt, StpHbr, StpKml, and StpKsr) and V. vexillata (L.) A. Rich, of five accessions (VexBgv, VexKrt, VexKdg, VexTnv and VexKut) with respective groups (G1and G2).This significant variability of the different characters of the diverse groups is most useful in future plant breeding programmes.

Key words*: cluster analysis, factor analysis, genetic variability, morphometric analysis, Western Ghats, wild Vigna.*

INTRODUCTION

The *Vigna* is the genus of the family Fabaceae, belongs to Phaseoleae tribe and its subtribe is Phaseolinae, which is distributed throughout the globe of the tropical and subtropical continents (Andargie et al., 2013; Jacob et al., 2015). The hierarchical position of the genus *Vigna* always have the controversial issues, earlier it has to be classified into the genus *Phaseolus* (Norihiko et al., 2001). It was always shown comprehensive in nature due to high significant in genetic variability as it exhibit morphometric characteristics and highly variable in their ecological distribution (Padulosi, 1997; Delgado-Salinas et al., 2011). Till today, more than hundred species of *Vigna* has been recognized around the globe (Thulin et al., 2004; Delgado-Salinas et al., 2011; Takahashi et al., 2016). According to Verdcourt (1970) around sixteen wild *Vigna* has been recognized in Asian subcontinent and few claims as seventeen (Bisht et al., 2005) and Babu et al. (1985) also claims twenty three species of wild and cultivated forms of *Vigna* and their wild relatives like mungbean are widely distributed in India (Smartt, 1990; Chontira et al., 2007).

They are generally found in much unobstructed ecological vicinity such as grasslands, wetlands and sandy soils. The wild *Vigna* species are chief source for their remarkable characters as of the biotic and abiotic stress resistant and these are primarily considered to be utilized for food and medicine purposes (Ahuja and Singh, 1977; Ignacimuthu and Babu, 1984, 1987; Jacob et al., 2015). Henceforth their valuable distinct characters of adopting nature are most useful to the future plant breeding programmes, mainly great perspective for crop improvement.

The estimation of the correlation coefficient is affording major relativity of different traits of the wild *Vigna* species. Moreover, Principal Component (PC) and Factor Analysis (FA) significantly reduce the larger number of correlated variables in a small number of uncorrelated factors and hence it gives the possibility to identify the most distinctive characters. The principal component analysis primarily and consistently afford stability of the reproductive traits in taxonomic delimitation of species in the genus *Vigna* and it would also give information about high morphometric relationships among species according to Jacob et al. (2015). Furthermore, analysis of phylogenetic tree has most distinguished afford to classify the different clusters by the dendrogram construction for identifying the greater variability, which is more useful to the trait of interest for future crop plant breeding enhancement.

MATERIALS AND METHODS

The study was undertaken to germplasm collection and morphometric characterization of the sixteen accessions of the three wild *Vigna* species at different region of Western Ghats of Karnataka, Kerala and also parts of northern Karnataka were used to enhance the variability among the different collected accessions. The plants were identified using different Flora and reference books (Hooker, 1872-1897; Cecil and Dan, 1976; Gamble, 1984; Sanjappa, 1992; Bhat, 2003). Sixteen accessions of three wild species of *Vigna*, *V. vexillata* (L.) A. Rich, *V. stipulacea* Kuntze and *V. dalzelliana* var. *dalzelliana* (Kuntze) Verdc. were collected at the month of August to December during 2015 to 2017. The seeds were collected, processed and stored until further use.

For the analysis, seeds were used to quantify the morphological traits using descriptors of IBPGR (1983) and IPGRI (2006) data and observations were recorded. Using the earthen pots and plastic pots seeds were sown and plants were grown in the greenhouse. Figure 1 illustrates collected *Vigna* species samples during field visit. Table 1, 2 and 3 systematically depicts geographical regions, qualitative and quantitative characters of sixteen accessions of the wild *Vigna* species respectively. Qualitative traits were recorded based on visual approach while quantitative traits were taken into consideration for estimating substantial variation and relationships among species of wild *Vigna* accessions. The most important seven qualitative traits were used, viz., Growth habit, Terminal leaflet shape, Flower colour, Pod colour, Seed shape, Seed texture and Seed colour. Further the prominent thirteen quantitative traits were used, viz., Plant height (m), Terminal leaflet length (cm), Terminal leaflet width (cm), Peduncle Length (cm), Number of flower per raceme, Number of pods per peduncle, Pod length (cm), Seed length (mm), Seed width (mm), Hundred seed weight (g), Number of seeds per pod, Number of locules per pod and Seed set percentage were considered for estimating diversity. Mean values of all the accessions were computed for determining the analysis of variance and correlation coefficients were estimated by using data for significant characters were further subjected to statistical analysis such as range, mean, minimum, maximum, percent of variance was recorded and correlation coefficient also recorded for variability and consistency. Table 4 shows descriptive statistics and variance of traits of sixteen accessions of the wild *Vigna* species. Table 5 depicts the Pearson correlation coefficient among quantitative traits of sixteen accessions of wild *Vigna* species. Principal Component (PC) analysis (Table 6) and Factor Analysis (FA) (Table 7) was done using R version 3.4.4 (2018) statistical packages. Further, dendrogram (Figure 2) was constructed to classify the different groups and it helps to identify the genetic variability (Table 8 and 9) and their relationships using the IBM SPSS (2011) and all these analyses significantly provide morphological characteristics of relationships among wild *Vigna* species.

RESULTS AND DISCUSSION

Qualitative Evaluation of Morphological Characters

All the sixteen wild *Vigna* accessions investigated in this study varied considerably in

their morphometric traits. The variability expressed in their qualitative traits is shown in (Figure 1 and Table 2). All the three wild *Vigna* species exhibit twelve accessions (*VexKdg*, *VexBgv*, *VexKut*, *VexKrt*, *VexTnv*, *DalAgb*, *DalKrt*, *DalJof*, *DalBsg*, *DalMkf*, *DalKun* and *DalRnp*) with twining growth habits and four accessions were prostate with twining habits (*StpKnt*, *StpKml*, *StpKsr* and *StpHbr*).

Figure 1. Collection of Wild *Vigna* Species at Various Locations (A1 and A2 - *V. stipulacea*, B1 and B2 - *V. vexillata*, C1 and C2 - *V. dalzelliana*)

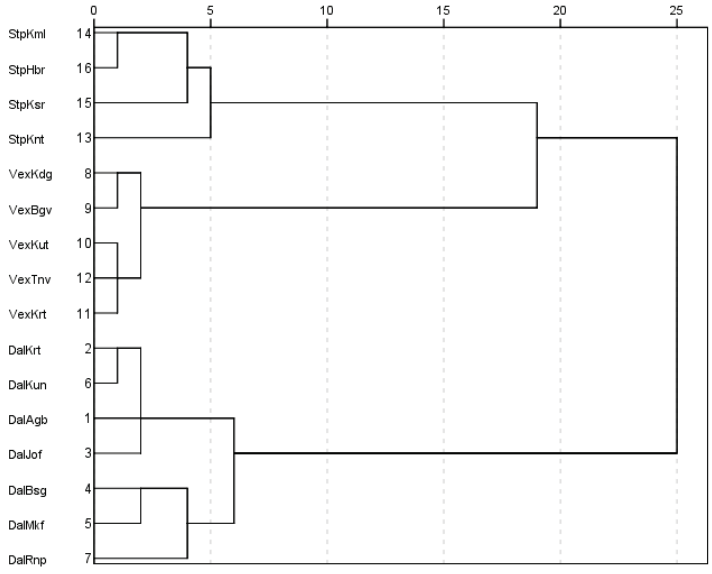

Figure 2. Dendrogram using Average Linkage (between groups) of Sixteen Accessions among Wild *Vigna* Species

And the variability expressed in terminal leaflet shape ovate to rhomboidal, ovate and narrowly ovate. It was also observed that the *Vigna* species vary in flower, pod and seed associated traits such as texture, shape and colour. The distinct flower colour observed in *Vigna* species includes yellow, pale yellow and slightly light purple colours. It was also noticed that, the pod and seed of the wild *Vigna* species varied in colour such as blackish, blackish brown and greyish black for the pod, while elliptic, round and rectangular for shapes, whereas smooth to rough for texture, although brownish with black mottled, black and grey mottled for seed colour. The qualitative morphological evaluation significantly described a high degree of taxonomic affinities of various accessions among the diversity in genus *Vigna*.

Table 1. Collection of Wild *Vigna* Species in Different Geographical Regions of Kerala and Karnataka

Accessions	Species	Location	State
StpKnt	*V. stipulacea*	Konanatambigi, Haveri, Northern Karnataka	Karnataka
StpKml	*V. stipulacea*	Kerimatthalli, Haveri, Northern Karnataka	Karnataka
StpKsr	*V. stipulacea*	Kiresur, Hubli, Northern Karnataka	Karnataka
StpHbr	*V. stipulacea*	Hebasur, Hubli, Northern Karnataka	Karnataka
VexKdg	*V. vexillata*	Sampigekatte, Kodagu, Western Ghats	Karnataka
VexBgv	*V. vexillata*	Belagaum, Western Ghats	Karnataka
VexKut	*V. vexillata*	Tholpetty, Kutta, Wayanad, Western Ghats	Kerala
VexKrt	*V. vexillata*	Kiravati, Joida, Karawar, Western Ghats	Karnataka
VexTnv	*V. vexillata*	Thirunelli, wayanad, Western Ghats	Kerala
DalAgb	*V. dalzelliana*	Agumbe, Shivamogga, Western Ghats	Karnataka
DalKrt	*V. dalzelliana*	Kiravati, Kumbharvad, Joida, Western Ghats	Karnataka
DalJof	*V. dalzelliana*	Jodafall, Sampanjegatt, Western Ghats	Karnataka
DalBsg	*V. dalzelliana*	Bisalegatt, Hassan, Western Ghats	Karnataka
DalMkf	*V. dalzelliana*	Mukkaalli forest,Pallacaud, Western Ghats	Kerala
DalKun	*V. dalzelliana*	Kundapura , Western Ghats	Karnataka
DalRnp	*V. dalzelliana*	Ranipuram, Kasragod, Western Ghats	Kerala

Correlation Coefficient for the Different Quantitative Traits

Results distinctly showed significant variations such as seed set percentage was positively correlated with plant height (0.407), terminal leaflet length (0.359), terminal leaflet width (0.295), pod length (0.320), seed length (0.289), seed width (0.080), seed weight (0.188), number of seeds per pod (0.445) and number of locules per pod (0.181). Whereas negatively correlated with peduncle length (-0.210), the number of flower per raceme (-0.421) and number of pods per peduncle (-0.344). The subsequent to that the number of locules per pod has been considered as the positively correlated with terminal leaflet width (0.231) and seed width (0.282). And also significantly positively correlated with plant height (0.774**), terminal leaflet length (0.790**), pod length (0.758**), seed length (0.693**), seed weight (0.688**) and number of seeds per pod (0.961**). While negatively correlated with peduncle length (-0.182) and also significantly negatively correlated with number of flower per raceme (-0.725**) and number of pods per peduncle (-0.642**).

Following to that, number of seeds per pod has been considered as positively correlated with terminal leaflet width (0.287) and seed width (0.285). Whereas significantly positively correlated with plant height (0.814**), terminal leaflet length (0.816**), pod length (0.784**), seed length (0.715**) and seed weight (0.684**). While negatively correlated with peduncle length (-0.217) and also significantly negatively correlated with the number of flower per raceme (-0.778**) and the number of pods

per peduncle (-0.683**). The next to that, seed weight has been positively correlated with plant height (0.328), terminal leaflet length (0.319) and peduncle length (0.452). Whereas significantly positively correlated with pod length (0.963**), seed length (0.954**) and seed width (0.754**). While negatively correlated with terminal leaflet width (-0.091) and also significantly negatively correlated with the number of flower per raceme (-0.679**) and the number of pods per peduncle (-0.866**).

Table 2. Quantitative Traits and their Mean Values of Sixteen Wild *Vigna* Accessions

Accessions	PHT	TLL	TLW	PEL	NFR	PDP	PDL	SDL	SDW	SWT	NOS	LPP	SSP
DalAgb	2.13	8.40	5.20	8.20	5.00	5.17	4.20	2.73	1.93	0.80	13.50	14.00	96.43
DalKrt	2.38	7.93	5.93	8.20	6.00	5.83	4.27	2.50	1.87	0.60	13.33	13.80	96.59
DalJof	2.20	7.87	5.80	7.67	6.10	6.00	4.13	2.57	1.67	0.67	13.50	14.20	95.07
DalBsg	2.18	7.80	5.73	7.53	6.17	6.17	5.28	2.77	1.83	0.70	13.00	13.10	99.24
DalMkf	2.12	7.95	6.00	7.67	5.83	5.80	4.13	2.63	1.80	0.57	14.00	14.00	100.00
DalKun	2.10	8.12	5.87	7.93	6.00	5.15	4.27	2.50	1.30	0.53	13.00	13.50	96.30
DalRnp	2.20	7.50	6.33	8.13	4.33	4.33	4.20	2.73	1.70	0.73	13.00	13.00	100.00
VexKdg	2.50	8.27	6.27	17.67	4.17	4.00	9.40	4.10	2.33	2.13	14.40	14.67	98.16
VexBgv	2.53	9.10	6.33	17.53	4.17	3.19	9.60	3.97	2.22	2.07	14.50	14.83	97.77
VexKut	2.43	8.17	4 .93	17.60	4.00	3.18	9.47	3.43	2.13	1.90	14.60	14.83	98.45
VexKrt	2.37	8.67	5.07	17.33	3.17	3.17	9.53	3.83	2.15	1.97	14.30	14.50	98.62
VexTnv	2.38	8.73	5.13	17.67	4.00	4.00	9.60	3.30	2.13	1.87	14.50	14.67	98.84
StpKnt	1.05	5.03	4.93	25.67	5.67	5.10	5.00	2.91	2.23	1.33	12.30	13.00	94.62
StpKml	1.09	5.33	4.80	25.33	8.00	5.67	4.87	2.67	2.07	0.87	12.50	13.00	96.15
StpKsr	1.17	5.27	5.00	25.80	6.33	4.83	5.07	2.87	2.22	1.00	12.80	13.00	98.46
StpHbr	1.07	4.83	4.87	25.00	8.00	5.67	4.98	2.73	2.00	0.93	12.60	13.00	96.92

PHT-Plant height (m), TLL-Terminal leaflet length (cm), TLW-Terminal leaflet width (cm), PEL-Peduncle length (cm), NFR -Number of flower per raceme, PDP- Number of pods per peduncle, PDL-Pod length (cm), SDL-Seed length (mm), SDW-Seed width (mm), SWT- Hundred Seed weight (g), NOS-Number of seeds per pod, LPP-Number of locules per pod, SSP-Seed set percentage.

The subsequently, the seed width has been considered as significantly positively correlated with the peduncle length (0.725**), pod length (0.633**) and seed length (0.690**). While negatively correlated with plant height (-0.150), terminal leaflet length (-0.176), terminal leaflet width (-0.354) and the number of flower per raceme (-0.266). Whereas significantly negatively correlated with number of pods per peduncle (-0.499*). In addition, seed length has been positively correlated with plant height (0.430), terminal leaflet length (0.416), terminal leaflet width (0.118) and peduncle length (0.317). Whereas significantly positively correlated with only pod length (0.929**). While significantly negatively correlated with the number of flower per raceme (-0.703**) and the number of pods per peduncle (-0.843**). The next to that, the pod length considered as positively correlated with plant height (0.471), terminal leaflet length (0.463) and peduncle length (0.313). While negatively correlated with terminal leaflet width (-0.038) and also significantly negatively correlated with the number of flower per raceme (-0.699**) and the number of pods per peduncle (-0.856**).

The number of pods per peduncle has been considered as significantly positively correlated with only number of flower per raceme (0.816**). While negatively correlated with plant height (-0.433), terminal leaflet length (-0.434), terminal leaflet width (-0.015) and peduncle length (-0.260). In addition to that, considered a number of flowers per raceme have been positively correlated with peduncle length (0.220) and negatively correlated with terminal leaflet width (-0.288). While significantly negatively correlated with plant height (-0.745**) and terminal leaflet length (-0.741**). Furthermore, that the peduncle length has been considered as the negatively

correlated with plant height (-0.674**), terminal leaflet length (-0.669**) and terminal leaflet width (-0.650**). Followed by that, considered terminal leaflet width has been significantly positively correlated with plant height (0.624**) and terminal leaflet length (0.557*). Finally, it was considered that terminal leaflet length has been significantly positively correlated with plant height (0.971**). Therefore present investigation of our analysis showed the considerable extensive variations in different parameters of the wild *Vigna* accessions in Pearson Correlation Coefficient analysis (Table 5).

Table 3. Characterization of Sixteen Accessions of Wild *Vigna* Species According to Their Qualitative Traits

Accession	Growth habit	Terminal leaflet shape	Flower colour	Pod colour	Seed shape	Seed texture	Seed colour
StpKnt	Prostate with twining	Ovate to rhomboidal	Yellow	Blackish brown	Elliptic	Rough	Brownish with black mottled
StpKml	Prostate with twining	Ovate to rhomboidal	Yellow	Blackish brown	Elliptic	Rough	Brownish with black mottled
StpKsr	Prostate with twining	Ovate to rhomboidal	Yellow	Blackish brown	Elliptic	Rough	Brownish with black mottled
StpHbr	Prostate with twining	Ovate to rhomboidal	Yellow	Blackish brown	Elliptic	Rough	Brownish with black mottled
VexKdg	Twining	Narrowly ovate	Slightly purple	Greyish black	Rounded	Smooth	Black
VexBgv	Twining	Narrowly ovate	Slightly purple	Greyish black	Rounded	Smooth	Black
VexKut	Twining	Narrowly ovate	Slightly purple	Greyish black	Rounded	Smooth	Black
VexKrt	Twining	Narrowly ovate	Slightly purple	Greyish black	Rounded	Smooth	Black
VexTnv	Twining	Narrowly ovate	Slightly purple	Greyish black	Rounded	Smooth	Black
DalAgb	Twining	Ovate	Pale yellow	Greyish black	Rectangular	Smooth	Grey mottled
DalKrt	Twining	Ovate	Pale yellow	Greyish black	Rectangular	Smooth	Grey mottled
DalJof	Twining	Ovate	Pale yellow	Greyish black	Rectangular	Smooth	Gray mottled
DalBsg	Twining	Ovate	Pale yellow	Greyish black	Rectangular	Smooth	Gray mottled
DalMkf	Twining	Ovate	Pale yellow	Greyish black	Rectangular	Smooth	Gray mottled
DalKun	Twining	Ovate	Pale yellow	Greyish black	Rectangular	Smooth	Gray mottled
DalRnp	Twining	Ovate	Pale yellow	Greyish black	Rectangular	Smooth	Gray mottled

Principal Component Analysis of the Sixteen Accessions of Wild *Vigna* Species

Among the thirteen PC, first, two PC were observed to have influenced the variation with 82.00% of the total variations (Table 6). The PC-1 alone accounted for 54.00% of the proportion variation, which was mainly directly influenced by traits such as the floral characters as the number of flower per raceme (0.334) and reproductive traits as the number of pods per peduncle (0.321), most important traits they are directly correlated to the variations while only vegetative traits as of peduncle length was

shown because here there is no correlation to the PC-1.

Followed by that, the PC-2 revealed for 28.00% of the total variation and their cumulative variations 82.00%, which were often directly influenced by some vegetative traits such as peduncle length (0.518) and reproductive characters were as seed width (0.416), seed weight (0.268), seed length (0.193), pod length (0.191) while there is no correlation of some floral traits as of the number of flower per raceme and reproductive characters as the number of seeds per pod and seed set percentage. Hence the principal component analysis provides the vast phenetic relationship among the species, the superior qualities of wild *Vigna* has to provide the potential for plant breeding programmes.

Factor Analysis of the Sixteen Accessions of Wild *Vigna* Species

The results of factor analysis (Table 7), it has been revealed that the variance of each factor shows its importance; on the other hand, the sign of factors coefficients in each factor represent the relationship among the characters. All the four factors described that of 90.00% of total variations. The first factor, which accounted that the proportion variation of 42.00%, was strongly associated with the vegetative trait of the peduncle length (0.428) and floral trait of the number of flower per raceme (-0.692) and reproductive traits such as the number of pod per peduncle (-0.864), pod length (0.928), seed length (0.946), seed width (0.713) and seed weight (0.972) that indicate the importance of these traits in breeding the yield in *Vigna* species and this factor were regarded as the primary degree of yield in *Vigna* species.

Followed by that, the second factor which noted to proportion variations of 28.00% and the cumulative variance of 70.00% was strongly predicted with vegetative traits as of the plant height (0.845), terminal leaflet length (0.829) and terminal leaflet length (0.710). Subsequently to that, the third factor described as the proportion variations of 12.00% and cumulative variance of 82.00% was revealed with reproductive traits such as the number of seeds per pod (0.661) and the number of locules per pod (0.710). Finally, the fourth factor accounted for 8.00% of proportion variance and cumulative variance of 90.00% with reproductive traits of seed set percentage (0.949). Hence Factor Analysis (FA) significantly reduces the bigger wide variety of correlated variables in a small range of uncorrelated factors and for this the reason, it offers the possibility to pick out the greatest one of a kind characters.

Cluster Analysis of the Sixteen Accessions of Three Wild *Vigna* Species

The hierarchical cluster analysis was carried out using an average linkage (between groups) methods (Figure 2). On the basis of thirteen morphometric quantitative characters were used in order to estimate the genetic distance between the sixteen wild *Vigna* accessions (Table 8) and prominent traits were predicted (Table 9). Based on dendrogram construction it was clearly distinguished the two main clusters at the 6% to 19% level of the cut made the seven accessions of species *V. dalzelliana* var. *dalzelliana* and nine accessions of species such as *V. stipulacea* and *V. vexillata*, with respectively (Figure 2). Further, these two clusters are classified at less than 6% level the point made into the sub-clusters is also named as groups. The first group (G1) is considered as cluster classified at 5% level species of *V. stipulacea*, four lines reveal 25% of accessions (*StpKnt*, *StpHbr*, *StpKml* and *StpKsr*). According to the findings, these accessions are mainly characterized by primarily on vegetative characters as of highest level of peduncle length (25.45cm) and floral traits as the number of flower per raceme (7.00). Whereas the lowest level of vegetative traits such as plant height (1.10m), terminal leaflet length (5.12cm) and terminal leaflet width (4.90cm) and reproductive traits such as the number of seeds per pod (12.55) and the number of locule per pod (13.00). The second group (G2) made by at 3% level classify the *V. vexillata* and were grouped about 31.25% of five accessions (*VexBgv*, *VexKrt*, *VexKdg*,

Table 4. Descriptive Statistics and Variance of Traits of Sixteen Accessions of the Wild *Vigna* Species

Traits	Range	Minimum	Maximum	Mean	Standard Error	Standard Deviation	Variance
Plant height (m)	1.48	1.05	2.53	1.99	0.14	0.55	0.31
Terminal leaflet length(cm)	4.27	4.83	9.10	7.44	0.36	1.44	2.08
Terminal leaflet width (cm)	1.53	4.80	6.33	5.51	0.14	0.57	0.33
Peduncle length (cm)	18.27	7.53	25.80	15.31	1.85	7.40	54.76
Number of flower per raceme	4.83	3.17	8.00	5.43	0.35	1.41	1.98
Number of pods per peduncle	3.00	3.17	6.17	4.83	0.26	1.05	1.11
Pod length(cm)	5.47	4.13	9.60	6.13	0.60	2.39	5.73
Seed length (mm)	1.60	2.50	4.10	3.02	0.13	0.54	0.29
Seed width (mm)	1.03	1.30	2.33	1.97	0.07	0.27	0.07
Hundred seed weight (g)	1.60	0.53	2.13	1.17	0.15	0.61	0.37
Number of seeds per pod	2.30	12.30	14.60	13.49	0.20	0.79	0.63
Number of locules per pod	1.83	13.00	14.83	13.82	0.18	0.74	0.54
Seed set percentage	5.38	94.62	100.00	97.60	0.41	1.64	2.70

Table 5. Pearson Correlation Coefficient among the Quantitative Traits of the Sixteen Accessions of Wild *Vigna* Species

Traits	PHT	TLL	TLW	PEL	NFR	PDP	PDL	SDL	SDW	SWT	NOS	LPP	SSP
PHT	1												
TLL	.971**	1											
TLW	.624**	.557*	1										
PEL	-.674**	-.669**	-.650**	1									
NFR	-.745**	-.741**	-.288	.220	1								
PDP	-.433	-.434	-.015	-.260	.816**	1							
PDL	.471	.463	-.038	.313	-.699**	-.856**	1						
SDL	.430	.416	.118	.317	-.703**	-.843**	.929**	1					
SDW	-.150	-.176	-.354	.725**	-.266	-.499*	.633**	.690**	1				
SWT	.328	.319	-.091	.452	-.679**	-.866**	.963**	.954**	.754**	1			
NOS	.814**	.816**	.287	-.217	-.778**	-.683**	.784**	.715**	.285	.684**	1		
LPP	.774**	.790**	.231	-.182	-.725**	-.642**	.758**	.693**	.282	.688**	.961**	1	
SSP	.407	.359	.295	-.210	-.421	-.344	.320	.289	.080	.188	.445	.181	1

*Correlation is significant at the 0.05% level of probability, **Correlation is significant at the 0.01% level of probability, Traits- PHT-Plant height (m), TLL-Terminal leaflet length (cm), TLW-Terminal leaflet width (cm), PEL-Peduncle length (cm), NFR -Number of flower per raceme, PDP-Number of pods per peduncle, PDL-Pod length (cm), SDL-Seed length (mm), SDW-Seed width (mm), SWT- Hundred seed weight (g), NOS-Number of seeds per pod, LPP-Number of locules per pod, SSP-Seed set percentage.

and *VexKut*). Hence the study indicated that they exhibit the most distinct characters such as highest level of vegetative traits mainly of plant height (2.44m), terminal leaflet length (8.59cm) and reproductive traits such as pod length (9.52cm), seed length (3.73mm), seed weight (1.99g) the number of seeds per pod (14.46) and the number of locule per pod (14.70). On other hand, lower values recorded the floral characters as number of flower per raceme (3.90) and also a few reproductive characters as the number of pods per peduncle (3.51) were considered. Followed by that, the third group (G3) was classified at the 3% level exhibiting the four lines of 25% of *V. dalzelliana* var. *dalzelliana*, of accessions (*DalKrt*, *DalAgb*, *DalKun* and *DalJof*). These were considerably showed higher values the number of pods per peduncle (5.54). Whereas lower values recorded reproductive traits mainly the pod length (4.22cm) and seed length (2.58mm), seed width (1.69mm) and seed weight (0.65g).

The finally, fourth group (G4) classified at the 6% level, have the three lines about 18.75% of the *V. dalzelliana* var. *dalzelliana* of accessions (*DalMkf*, *DalBsg* and *DalRnp*). Which showed higher values of terminal leaflet width (6.02cm) and seed set percent (99.75%), however lower values in the peduncle length (7.78cm) recorded. As a result the dendrogram

structure were distinguished nearly at the 6% level of the distance which exhibits in the first main cluster whereas the two sub-cluster of such as group (G3 and G4), which are closely associated relatives of *V. dalzelliana* var. *dalzelliana* of accessions (*DalKrt*, *DalAgb*, *DalKun* and *DalJof*) and (*DalMkf*, *DalBsg* and *DalRnp*) with respectively and they were placed very evidently associated with traits of mainly on vegetative, floral and reproductive.

Table 6. Contribution of the Thirteen Quantitative Traits to the Total Variation in the First Two Principal Componet Analysis of Sixteen Wild *Vigna* Accessions

Variables	Principle component (PC-1)	Principle component (PC-2)
Plant height (m)	-0.285	-0.331
Terminal leaflet length (cm)	-0.281	-0.327
Terminal leaflet width (cm)	-0.101	-0.376
Peduncle length (cm)	–	0.518
Number of flower per raceme	0.334	–
Number of pods per peduncle	0.321	-0.157
Pod length(cm)	-0.339	0.191
Seed length (mm)	-0.331	0.193
Seed width (mm)	-0.164	0.416
Hundred seed weight (g)	-0.318	0.268
Number of seeds per pod	-0.351	–
Number of locules per pod	-0.335	–
Seed set percentage	-0.164	-0.115
Proportion variance	54.00	28.00
Cumulative variance	54.00	82.00

Table 7. The Factor Analysis using Varimax (orthogonal) Rotation for Thirteen Traits and Seed Yield in Wild *Vigna* Accessions

Traits	Factor-1	Factor-2	Factor-3	Factor-4
Peduncle length (cm)	**0.428**	-0.885	-0.136	-
Number of flower per raceme	**-0.692**	-0.534	-0.175	-0.163
Number of pods per peduncle	**-0.864**	–	-0.153	-0.158
Pod length(cm)	**0.928**	–	0.292	0.126
Seed length (mm)	**0.946**	–	0.170	–
Seed width (mm)	**0.713**	-0.495	–	–
Hundred seed weight (g)	**0.972**	–	0.210	–
Plant height (m)	0.318	**0.845**	0.381	0.135
Terminal leaflet length (cm)	0.300	**0.829**	0.423	–
Terminal leaflet width (cm)	–	**0.710**	–	0.141
Number of seeds per pod	0.589	0.410	**0.661**	0.215
Number of locules per pod	0.584	0.384	**0.710**	–
Seed set percentage	0.189	0.237	–	**0.949**
Proportion variance (%)	42.00	28.00	12.00	8.00
Cumulative variance (%)	42.00	70.00	82.00	90.00

Furthermore, the dendrogram structure was resulted at nearly about 19% and exhibited and which are arranged to classify very distantly in two separate groups as the *V. stipulacea* of four accessions (*StpKnt*, *StpHbr*, *StpKml* and *StpKsr*) and *V. vexillata*, of five accessions (*VexBgv*, *VexKrt*, *VexKdg*, *VexTnv* and *VexKut*) with the respective group (G1and G2) and morphologically vegetative, floral and reproductive traits are very distinctive were considered (Figure 2, Table 9).

Table 8. Mean of Quantitative Traits of Sixteen Accessions of Wild *Vigna* Species

Variables	Group-1	Group-2	Group-3	Group-4
Plant height (m)	1.10	2.44	2.20	2.17
Terminal leaflet length (cm)	5.12	8.59	8.08	7.75
Terminal leaflet width (cm)	4.90	5.55	5.70	6.02
Peduncle length (cm)	25.45	17.56	8.00	7.78
Number of flower per raceme	7.00	3.90	5.78	5.44
Number of pods per peduncle	5.32	3.51	5.54	5.43
Pod length(cm)	4.98	9.52	4.22	4.54
Seed length (mm)	2.80	3.73	2.58	2.71
Seed width (mm)	2.13	2.19	1.69	1.78
Hundred seed weight (g)	1.03	1.99	0.65	0.67
Number of seeds per pod	12.55	14.46	13.33	13.33
Number of locules per pod	13.00	14.70	13.88	13.37
Seed set percentage	96.54	98.37	96.10	99.75

Table 9. Most Prominent Traits of Sixteen Wild *Vigna* Accessions

Main group	Number of lines	Percentage of lines	Sub-cluster lines	Prominent traits of wild *Vigna*
I	4	25	*StpKnt, StpKml, StpKsr, StpHbr*	Highest: Peduncle length, Number of flower per raceme Lowest: Plant height, Terminal leaflet length, Terminal leaflet width, Number of seeds per pod and Number of locules per pod
II	5	31.25	*VexKdg, VexBgv, VexKut, VexKrt, VexTnv*	Highest: Plant height, Terminal leaflet length, Pod length, Seed length, Seed weight, Number of seeds per pod and Number of locules per pod Lowest: Number of flower per raceme and Number of pods per peduncle.
III	4	25	*DalAgb, DalKrt, DalJof, DalKun*	Highest: Number of pods per peduncle Lowest: Pod length, Seed length, Seed width and Hundred Seed weight
IV	3	18.75	*DalBsg, DalMkf, DalRnp*	Highest: Terminal leaflet width, Seed set percentage Lowest: Peduncle length

CONCLUSION

The morphometric analysis was considered to study vegetative, floral and reproductive traits to assess specific variations among sixteen accessions of *Vigna* species. The considerable largest variations found in peduncle length, lowest variations found in some reproductive traits of seed width. The correlation coefficient for the different quantitative traits distinctly showed the most important variations among the selected traits of vegetative and reproductive characters. The principal component (PC) analysis provides a comprehensive characterization of *Vigna* species based on quantitative traits. The first two PC results influenced the variation with 82.00% of the total variations. The first principal component alone accounted for 54.00% of total variation, which was directly influenced by traits such as floral characters mainly the number of flower per raceme and reproductive traits focusing number of pods per peduncle, which are known to be most important traits. The factor analysis results from all the four factors accounted that of 90.00% of total variations. The first factor was strongly associated with the vegetative trait of peduncle length and floral traits mainly the number of flower per raceme and reproductive traits such as the number of pod per peduncle, pod length seed length, seed width and seed weight. The dendrogram analysis distinguished about 6% level of the two groups (G3 and G4), which are closely associated relatives of *V. dalzelliana* var. *dalzelliana* and at 19% level clusters classified in two separate groups as the

V. stipulacea and *V. vexillata*, with the respective group (G1 and G2). Hence based on the experimental results a distinctive array of species variability has been investigated among the genus *Vigna* species of wild accessions. These significant variations of the different characters of diverse groups are most useful to explore future plant breeding programmes and sustainable conservation.

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