DIVA-GIS approaches for diversity assessment of pod characteristics in black gram (*Vigna mungo* L. Hepper)

Black gram (*Vigna mungo* (L.) Hepper) is one of the major grain legumes in the rainfed agro-ecosystems of India. It is native to India and has been cultivated since ancient times. It has also been introduced to other tropical regions of the world by Indian immigrants. It is grown in cropping systems as a mixed crop, catch crop, sequential crop besides being grown as sole crop under residual moisture conditions after the harvest of rice and also before and after the harvest of other summer crops under semi-irrigated and dry land conditions[1]. It has high nutritive value and is rich in proteins, essential vitamins and minerals. It is very popular in south Indian and Punjabi cuisine. The split dal is extensively used in culinary preparation like dosa, idli, vada and papad.

Andhra Pradesh, Maharashtra, Orissa, Madhya Pradesh, Tamil Nadu, Gujarat, Karnataka and Uttar Pradesh are major black gram cultivating states in India. Annual production in India ranges from 1.3 to 1.5 million tonnes and contributes to 10% of total pulse production[2]. Genetic resources of any crop are the cornerstone for breeding improved varieties. With this in view, collections of black gram were made from 17 districts of Andhra Pradesh during explorations undertaken in different agroclimatic regions of Andhra Pradesh from 1998 to 2004. The accessions were evaluated for different morphological traits to study the variations. Here we have attempted to integrate DIVA-GIS software (www.DIVA-GIS.org) for the diversity analysis of pod characters in black gram germplasm.

One hundred and sixty three samples of black gram were collected from fields following the random sampling procedure. Global Positioning System (Garmin-12) was used to record the geographical coordinates of the collection sites. The collections were grown in the experimental farm of the National Bureau of Plant Genetic Resources, Regional Station, Hyderabad during the kharif (rainy) and rabi (post rainy) seasons of 2005–06 following standard package of practices[3]. Data were recorded on six quantitative characters, viz. pod clusters/plant, pods/cluster, pods/plant, pod length, seeds/pod and test (100 seed) weight. Five plants of each accession were selected for recording data on pod clusters/plant, pods/cluster and pods/plant. Ten randomly selected pods drawn from the total number of pods harvested from five plants of each accession were used for recording pod length and seeds/pod. Data on mature pod colour and pod pubescence (qualitative traits) were recorded following the minimal descriptors published by the National Bureau of Plant Genetic Resources[4]. Digimatic calipers (Mitutoyo, Japan) was used to measure the pod characteristics. DIVA-GIS software version 5.2 freely downloadable from internet source (www.DIVA-GIS.org) was used for the analysis of diversity in quantitative pod traits coordinated with geographical coordinates.

A total of 163 accessions collected from 108 villages in 68 mandals covering 18 districts of Andhra Pradesh were used for the present study (Table 1). These accessions were collected during several germplasm surveys organized by the regional station of National Bureau of Plant Genetic Resources (NBPGR) located at Hyderabad. The collection sites mapped are provided in Figure 1.

Table 1. Black gram germplasm collections from Andhra Pradesh

District	Accessions collected	Mandals	Villages	Geographical coordinates (range)	
				Latitude (N)	Longitude (E)
Adilabad	46	15	26	18°97′–19°46′	77°55′–78°59′
Chittoor	1	1	1	13°63′	78°96′
Cuddapah	1	1	1	14°27′	78°49′
East Godavari	3	1	3	17°27′	81°47′
Guntur	1	1	1	16°13′	80°57′
Khammam	7	3	4	16°92′–17°44′	80°37′–81°25′
Kurnool	11	7	9	15°21′–15°47′	79°25′–78°59′
Mahabubnagar	2	1	2	16°87′	77°62′
Medak	34	11	21	17°30′–18°52′	77°32′–78°62′
Nalgonda	3	2	2	17°17′	79°30′–79°80′
Nellore	5	3	4	14°25′–14°50′	79°34′–79°45′
Nizamabad	3	1	3	18°21′–18°24′	77°40′–78°49′
Prakasam	5	2	4	15°04′–15°20′	79°24′–79°37′
Ranga Reddy	16	3	5	17°27′–17°35′	77°55′–78°59′
Srikakulam	9	3	8	18°20′–18°58′	83°37′–84°35′
Visakhapatnam	7	6	7	17°27′–17°50′	81°47′–83°40′
Vizianagaram	7	5	5	18°32′–18°41′	83°06′–83°40′
West Godavari	2	2	2	17°00′–17°10′	81°18′–81°23′
Total	163	68	108		

Table 2. Descriptive statistical analysis of pod characteristics

	Germplasm						Check varieties		
Traits	Mean	Median	Min.	Max.	Sd	CV%	T-9	PU-19	LBG-20
Pods/cluster	4.27	4.19	2.00	6.97	0.85	20	5.7	6.7	6.0
Clusters/plant	17.38	17.51	4.36	28.29	4.78	28	33.3	32.9	31.8
Pods/plant	44.81	45.18	6.73	79.83	15.53	35	65.2	64.4	62.2
Pod length	4.93	4.91	3.31	6.12	0.43	9	5.5	5.5	5.3
Seeds/pod	6.65	6.61	5.14	7.94	0.54	8	7.9	7.9	7.8
100 seed wt	4.67	4.72	2.09	6.91	1.01	22	6.5	6.5	6.7

Table 3. Inter-relationships between pod traits

Traits	Pods/cluster	Clusters/plant	Pods/plant	Pod length	Seeds/pod
Clusters/plant	0.374				
Pods/plant	**0.591***	**0.816***			
Pod length	–0.013	0.272	0.203		
Seeds/pod	–0.074	0.329	0.198	0.235	
100 seed wt	–0.008	0.024	–0.007	0.148	0.261

*Significant at P = 1%.

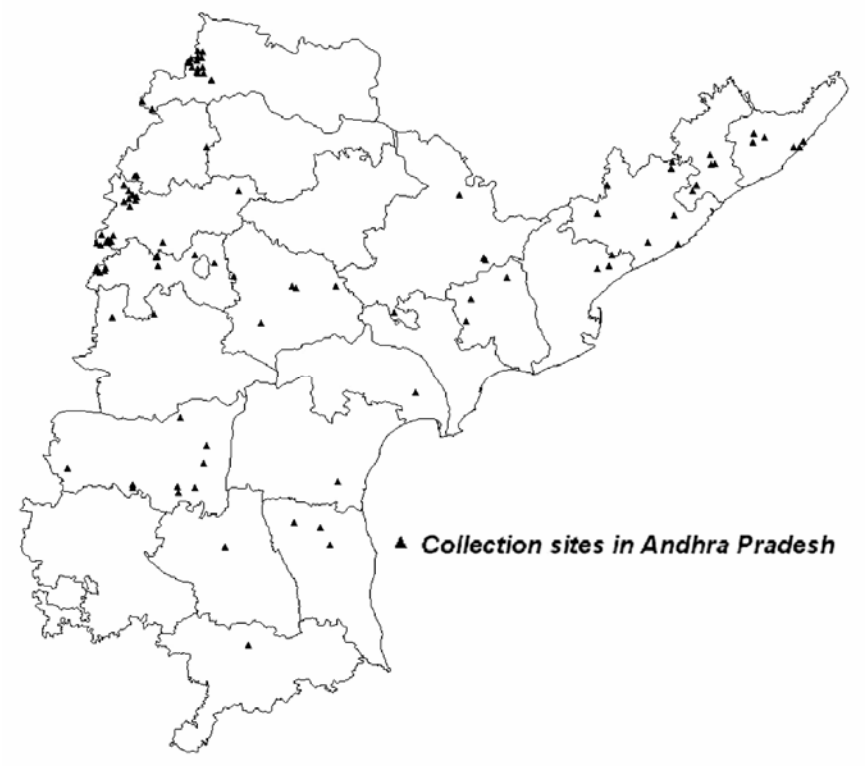

Figure 1. DIVA-GIS mapping of collection sites of black gram from Andhra Pradesh, India.

The black gram germplasm exhibited variability in all the six quantitative and two qualitative traits studied. The descriptive statistical analysis for the quantitative traits is given in Table 2. Variability exists in both the traits pod pubescence (glabrous-5; puberulent-77; moderately pubescent-37 and densely pubescent-44) and mature pod colour (brown-7; brownish black-56 and black-100). Similar characteristics were reported from India earlier by Dhirendra Singh *et al.*[5]. In addition, inheritance of pod pubescence and mature pod colour in black gram were reported earlier[6,7].

The largest pods are recorded in IC398980 (Nellore) and IC436729 (Adilabad) with an average pod length of 6.12 and 6.02 cm respectively, while the smallest pods were recorded in IC519835 (Visakhapatnam) and IC519684 (Vizianagaram), with mean pod length of 3.3 and 4 cm respectively. IC436792 and IC436789, both from Adilabad possessed maximum number of pods/plant (80 and 78 respectively) while IC426764 (Srikakulam) recorded the least with a mean value of 6.73 pods/plant. Test weight ranged from a minimum of 2.09 g to a maximum of 6.91 g recorded in IC519833 (Vizianagaram) and IC436717 (Adilabad) respectively. Estimates of correlation (Table 3) revealed significant (P = 1%) positive correlation of clusters/plant with pods/plant and pods/cluster with pods/plant. The first two principal components together explained 65% of the variations (Figure 2). There was no evidence of any specific grouping among the 163 accessions which largely clustered together along with the three check varieties.

GIS mapping is an excellent tool for documentation, preliminary diversity analysis, identifying gaps in collection, assessment of loss of diversity, developing new strategies for conservation, sustainable utilization, predict distribution, etc.

Grid maps were generated for the diversity index for pods/cluster (Figure 3) and clusters/plant (Figure 4). High diversity index for pods/cluster was observed in the collections made from parts of northern Telangana and western Telangana regions of Andhra Pradesh followed by southern Telangana, north coastal and Rayalaseema regions (Figure 3). The highest diversity index for number of clusters per plant was observed in

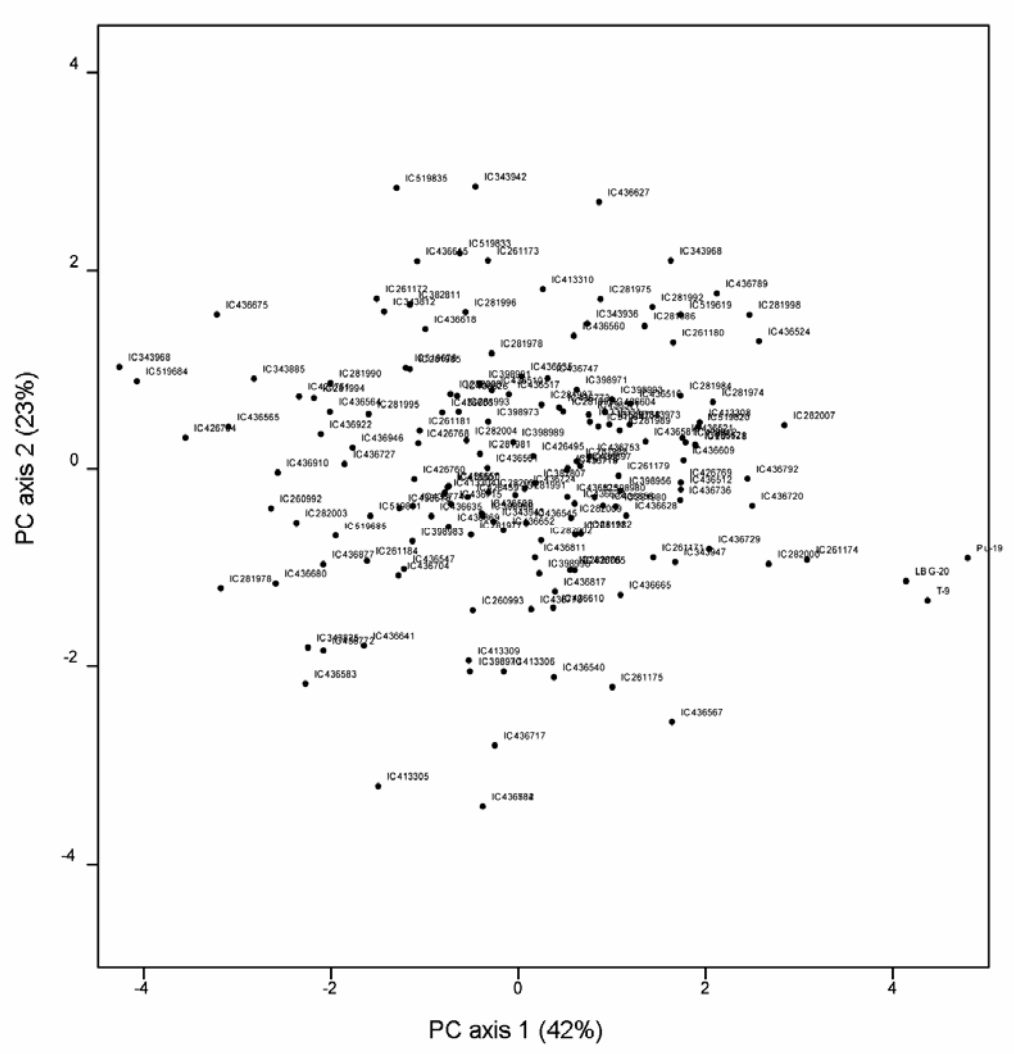

Figure 2. PCA plot of 163 accessions based on correlation of 6 pod traits.

Figure 3. Grid map showing diversity index for pods per cluster of black gram germplasm collected from Andhra Pradesh, India.

Figure 4. DIVA-GIS grid map showing the diversity index for clusters per plant in black gram germplasm.

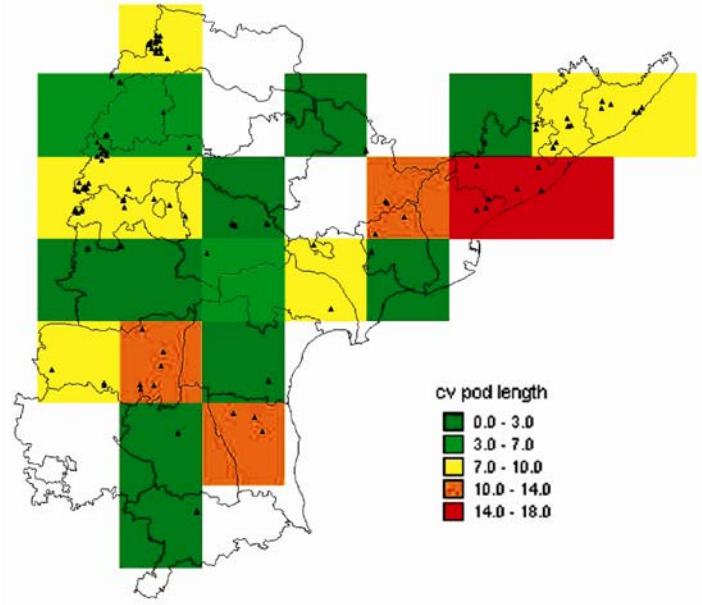

Figure 5. Coefficient of variation for black gram pod length analysed using DIVA-GIS.

the black gram collections made from the north western parts of Andhra Pradesh followed by southern Telangana, north coastal and Rayalaseema regions (Figure 4). The highest coefficient of variation for pod length was recorded in north coastal region (comprising parts of Visakhapatnam and East Godavari districts) followed by parts of West Godavari, Prakasam and Kurnool districts of Andhra Pradesh (Figure 5), indicating that diverse accessions are available in these districts. GIS mapping has been successfully used in the recent past in assessing the biodiversity and in identifying areas of high diversity (*Phaseolus* bean[8], wild potatoes[9], forest vegetation[10–12], agro biodiversity[13], medicinal plants[14] and *Piper*[15]).

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BABU ABRAHAM[1,*]
V. KAMALA[1]
N. SIVARAJ[1]
N. SUNIL[1]
S. R. PANDRAVADA[1]
M. VANAJA[2]
K. S. VARAPRASAD[1]

[1]*National Bureau of Plant Genetic Resources,*
Regional Station,
Hyderabad 500 030, India
[2]*Central Research Institute for Dryland Agriculture,*
Hyderabad 500 059, India
**For correspondence.*
e-mail: ubabham@gmail.com