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Studies on genetic diversity, variability, correlation and path analysis in black gram (*Vigna mungo*)

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Abstract
Black gram genotypes collected throughout Tamil Nadu representing different agroclimatic zones are taken for the study. Eight genotypes of black gram (*Vigna mungo)* were investigated to understand the existing pattern diversity, variability and correlation using twelve quantitative traits. Genetic diversity studies were made in using Mahalanobis D^2 statistics. The variability studies showed that plant height, number of branches per plant and had higher estimates of genotypic and phenotypic coefficient of variation. Heritability estimates were high for all the characters. Genetic advance as percentage of mean was high for plant height, pod length, number of clusters per plant, number of pods per plant, days to 50% flowering, number of seeds per plant, number of primary branches, days to maturity, 100 seed weight and grain yield per plant. Mahalanobsis analysis established the presence of wide genetic diversity among the genotypes and they were grouped into four clusters. Among the four clusters, cluster I was the largest with five genotypes and other clusters had only one genotype. The inter relationship among the characters revealed that selection based on number of pods per plant, number of branches per plant, number of clusters per plant and number of seeds per pods will be effective as they are highly correlated with grain yield. Partitioning correlation coefficients into direct and indirect effects by path coefficient analysis indicated that number of seeds per pod and pod length were the major yield contributing characters and have to adequate given selection pressure for improving grain yield. Considering all the diversity, mean performance and quantitative characters studied, the genotypes MDU 1, Nirmala and VBN 9 were found to be best for yield improvement programmes in black gram.

Keywords: Genetic diversity, variability, heritability, genetic advance, correlation, path analysis

Introduction
Black gram **(***Vigna mungo*) is one of the most important pulse crops grown throughout the world. The wide adaptability and stress tolerance of black gram makes it a good source of protein for people throughout the world. Pulses are the second largest class of food crops grown globally in about 22 million hectare. In India, black gram is cultivated in an area of 4.6 m. ha with an annual production 24.5 lakh tonnes, with an average productivity of 533 kg/ha. In India black gram occupies 19% total area under pulse and contributes 23% of total pulse production. About 70% of world's black gram production is from India. Black gram is good source of carbohydrates, protein, vitamins and minerals. Black gram is an important source of protein in vegetarian diet. Black gram is generally grown margin soil by resources poor farmers. Improving the yield level in black gram will have direct impact on the income and health of poor peasants.

Black gram exhibits a wide genetic diversity. Plant stature, seed size and colour, pod length and pod pubescence show a wide variation. Mahalanobis D^2 analysis is the commonly used and reliable method to study the diversity among the genotypes. In diversity studies using D^2 analysis, genotypes are selected, raised in the field, biometrical observations are taken and statistical analysis is made. The given set of genotypes is grouped in to different clusters and the distance between the clusters is arrived at. With these results, genotypes from more divergent clusters are selected and used as parents in breeding programmes.

The average grain yield of black gram in India ranges about 450 - 800 kg/ha which is lower than the potential yield. To improve the yield in cultivated black gram varieties, it is essential to study the diversity among genotypes and design breeding programmes based on the results and develop improved varieties and hybrids. There is a wide opportunity for crop improvement in black gram concentrating on yield, tolerance against pests, diseases and other abiotic stresses.

Materials and Methods

A total of eight genotypes of black gram were raised in Randomized Block Design with three replications at Sethu Bhaskara Agricultural College and Research Foundation, Karaikudi, during Kharif 2022. The genotypes were collected from National Research Centre for Pulses, Vamban, Agricultural College and Research Institute, Madurai and local markets of Karaikudi and Madurai. The list of genotypes along with their place of collection is given in Table 1. Biometrical observations were taken. The biometrical characters taken for the study are days to 50% flowering, plant height, leaf length, leaf width, number of branches per plant, pod length, number of clusters per plant, number of pods per plant, days to maturity, number of seeds per pod, 100 seed weight and grain yield per plant.

Table 1: List of genotypes and their place of collection

S. No	Varieties	Source
1.	Vamban 6	National Research Centre for Pulses, Vamban
2.	Vamban 8	National Research Centre for Pulses, Vamban
3.	Vamban 9	National Research Centre for Pulses, Vamban
4.	Vamban10	National Research Centre for Pulses, Vamban
5.	Vamban 11	National Research Centre for Pulses, Vamban
6.	MDU 1	Agricultural College And Research Institute, Madurai
7.	T 9	Seed market, Karaikudi
8.	Nirmala	Seed market, Madurai

Statistical Analysis

The estimates of mean, variance and standard error were worked out by adopting the standard methods (Panes and Sukhatme, 1961) [8].

Phenotypic and Genotypic Variance

These were estimated according to the formula given by Lush (1940) [6]

Genotypic variance ($\sigma^2 g$) = M1-M2/ r
Phenotypic variance ($\sigma^2 p$) = $\sigma^2 g + \sigma^2 e$

Phenotypic and Genotypic Coefficients of Variance

For each character, phenotypic and genotypic coefficients of variability (PCV and GCV) were computed based on the method given by Burton (1952) [2]

PCV% = PV/MEAN x 100
GCV% = GV/MEAN x 100

Heritability and genetic advance

Heritability (h^2) in a broad sense was calculated according to Lush (1940) [6]

h^2 (Broad sense) = $\sigma^2 g \backslash \sigma^2 p$ x 100

Genetic advance was expressed as percentage of mean by using the formula suggested by Johnson et al., (1955) [4]
Genetic advance as percentage of mean = genetic advance\grand mean x 100

Mahalanobis D^2 statistics

The quantitative characters were alone taken into consideration for divergence studies. For determining the group consideration, a relatively simple criterion by Rao (1952) [9] was followed. The criterion of grouping that any two populations belonging to the same cluster is at least on the average show a similar D^2 than those belonging to different clusters. After establishing the clusters, the intra cluster distances were worked out taking the average of the component genotypes in that cluster. The average inter cluster divergences were arrived at by taking into considerations, all the component D^2 values possible among the members of the two clusters considered.

Correlation and path coefficient analysis

The genotypic correlation coefficients between yield and yield components as well as among the yield components were worked out. From the analysis of variance and covariance tables, the corresponding genotypic variance and covariance were calculated by using the mean square values and mean sum of products as suggested by Al-Jibouri et al.,(1958). The relative influence of twelve components on yield by themselves and through other traits was evaluated by the methods of path coefficient analysis as suggested by Dewey and Lu (1959). The direct and indirect effects were classified based on the scales given by Lenka and Misra (1973) [5].

Results

Genetic Variability

The Genotype VBN 11 was earlier to flower whereas VBN 8 took longer days for 50% flowering. Among the 8 Genotypes MDU 1 was the tallest and VBN 10 was the shortest. The Maximum leaf length was observed in VBN 9 and minimum leaf length was found in VBN 6. Among the 8 genotypes the maximum leaf width was observed in VBN 11 and the minimum leaf length in VBN 10. The Minimum number of branches was observed in genotype VBN 10 while Nirmala had produced more number of branches per plant. The Minimum number of clusters was found in the T9 and maximum number of clusters in VBN 6. The Maximum number of pods was observed in VBN 8 and minimum number of pods in VBN 6. The genotype VBN 8 was found to have the maximum pod length and the minimum pod length was observed in VBN 10. The maximum number of seeds per plant was recorded in VBN 10 and minimum amount of seeds in Nirmala as suggested by Malarvizhli et al., (2005) [7]. The Genotype VBN 11 was earlier to mature and the genotype T9 were took longer days to mature. The genotype VBN 9 was found to have maximum 100 seed weight whereas the genotype MDU 1 was found to have minimum seed weight. The Genotype Nirmala exhibited higher single plant yield and the minimum yield was found in Vamban 10. The mean values are given in table 2. The phenotypic and genotypic variances, heritability and genetic advance values are given in table 3.

Table 2: Mean performance of eight genotypes of black gram for twelve characters

Genotypes	Days to flowering	Plant height (cm)	Leaf length (cm)	Leaf width (cm)	No .of Primary branches	No. of clusters per plant	No. of Pods per plant	Pod length (cm)	No. of Seed per plant	Days to maturity	Hundred seed weight (g)	Grain Yield per Plant (g)
VBN 10	35.00	19.73	8.30	3.10	7.96	10.73	17.43	4.66	6.33	70.00	4.16	5.13
VBN 9	33.00	22.83	7.43	5.50	8.53	12.66	20.00	4.76	6.33	72.33	5.76	10.96
VBN 6	40.00	26.26	6.72	4.18	9.66	9.98	14.22	4.33	6.10	73.33	3.77	6.62
VBN 8	40.66	30.63	7.63	5.56	8.43	13.83	28.66	4.90	5.66	72.00	4.52	8.97
VBN 11	33.66	27.26	8.43	6.00	8.23	16.66	21.40	4.73	6.33	74.00	3.37	9.43
T9	34.00	27.66	6.93	5.46	9.23	17.90	22.10	4.80	5.60	74.00	4.73	6.53
MDU1	33.00	31.23	7.05	4.83	12.10	12.09	23.63	4.23	6.00	72.00	4.74	10.59
Nirmala	33.33	29.50	7.26	4.36	15.33	13.63	27.33	4.73	5.46	72.00	4.94	11.16
Grand Mean	35.33	26.89	7.47	4.87	9.93	13.43	21.84	4.64	5.97	72.45	4.50	8.67
SED	0.95	1.17	0.60	0.12	0.48	1.12	1.30	0.07	0.18	1.03	0.07	0.79
CD (5%)	2.90	3.58	1.84	0.36	1.48	3.40	3.96	0.22	0.55	3.14	0.21	2.40

Table 3: Variability, Heritability and Genetic advance in eight diverse accessions of black gram

S. No.	Characters	Variance			CV%	PCV%	GCV%	Heritability	Genetic advance
		PV	GV	EV					
1	Days to 50% flowering	11.79	9.05	2.74	4.68	9.72	8.51	76.74	15.36
2	Plant height (cm)	18.27	14.10	4.17	7.59	15.89	13.96	77.16	25.27
3	Leaf length (cm)	1.12	0.02	1.09	14.03	14.16	1.92	1.85	0.54
4	Leaf width (cm)	0.93	0.89	0.04	4.28	19.89	19.39	95.35	39.02
5	No of primary branches	6.96	6.24	0.71	8.53	26.55	25.14	89.66	49.05
6	No of clusters per plant	9.96	6.19	3.77	14.45	23.48	18.51	62.14	30.06
7	No of pods per plant	26.41	21.32	5.09	10.33	23.52	21.13	80.71	39.11
8	Pod length (cm)	0.06	0.04	0.01	2.81	05.55	4.79	74.35	8.50
9	No of seeds per pod	0.19	0.09	0.10	5.32	07.39	5.13	48.18	7.33
10	Days to maturity	3.88	0.67	3.21	2.47	02.72	1.13	17.30	0.96
11	100 seed weight (g)	0.55	0.54	0.01	2.72	16.57	16.35	97.30	33.22
12	Grain yield per plant (g)	6.55	4.67	1.88	15.80	29.50	24.91	71.31	43.34

Composition of D^2 Analysis

The observation on 12 quantitative characters in eight genotypes of black gram were analysed for genetic diversity. The mean values of the eight genotypes were transformed into standardized uncorrelated mean values. The D^2 values corresponding to all possible combinations among the eight genotypes were computed. The clustering pattern revealed that the distribution of genotypes into different clusters was at random with regard to their geographical origin. Among the four clusters, it was observed that the cluster I has highest number of genotypes and the other clusters II , III and IV had only one genotype. The inter and intra cluster D^2 values among four clusters were arrived. The maximum intra cluster distance was recorded in cluster I. Whereas the minimum inter cluster distance was recorded in cluster II. The data on the means of all the twelve character are presented in table 7, it is evident that different cluster exhibit distinct mean values for all most all the twelve characters. A wide range was observed among different cluster for all the cluster means .Cluster I had highest mean value for days to 50 % flowering, plant height, number of primary branches and number of pods per plant. Cluster II had the maximum mean value for number of seeds per pod. Cluster III had the highest value for leaf length, leaf width, number of seeds per pod, days to maturity and number of cluster per plant. Cluster IV has the maximum mean value for pod length, Number seeds per pod and 100 seed weight. The composition of different clusters is given in table 4. The intra and inter cluster distance is given in table 5.

Table 4: Composition of D^2 Clusters on Black gram germplasm

Cluster	Number of genotypes	Name of the genotypes
I	5	VBN 8, T9, MDU 1, VBN 6 and Nirmala
II	1	VBN 10
III	1	VBN 11
IV	1	VBN 9

Table 5: Average Inter and Intra Cluster Values by Using D_2 Statistics

Clusters	I	II	III	IV
I	542.14	824.69	1074.19	949.62
II	0		1260.63	1620.87
III	0			2138.12
IV	0			

Genotypic and phenotypic correlation coefficients between different traits

For days to 50% flowering, a positive correlation was observed with plant height and a negative correlation with all other traits. Plant height is positively correlated with Number of cluster per plant, Number of pods per plant, Pod length, Days to maturity, 100 seed weight and the other characters are negatively correlated. Leaf length is positively correlated all characters except pod length, Number of seeds per pod and 100 seed weight. Leaf width exhibited positive correlation with Number of pods per plant, pod length, Number of seeds per pod, grain yield per plant. Number of Primary Branches positively correlated with all characters. Number of Clusters

per Plant had positive correlation with Number of pods per plant, Number of seeds per plant, 100 seed weight, Grain yield per plant and negative correlation was observed with pod length and Days to maturity. Number of pods per plant had positive correlation was observed by pod length, Days to maturity, Grain yield per plant and negative correlation with Number of seeds per pod and 100 seed weight. Pod length had positive correlation with Days to maturity, 100 seed weight and Grain yield per plant and negative correlation with Number of seeds per pod. Number of seeds per pod had positive correlation with 100 seed weight and the negative correlation with Days to maturity and Grain yield per plant. Days to maturity had positive correlation with Grain yield per plant and the negative correlation with 100 seed weight. 100 Seed weight had positive correlation with Grain yield per plant. The correlation coefficients between different traits are given in table 6 and 7.

Table 6: Genotypic and phenotypic (in bold) correlation and coefficients between different traits

S.no	Characters	Days to 50% flower	Plant Height (cm)	Leaf length (cm)	Leaf width(cm)	No of primary branches	No of cluster per plant	No of pods per plant	Pod length (cm)	No of seeds per pod	Days to maturity	100 seed weight (g)	Grain yield per plant
1	Days to 50% flowering		0.169 0.086	-0.494 -0.157	-0.092 -0.090	-0.303 -0.320	-0.380 0.260	-0.09 0.047	-0.007 0.032	-0.223 -0.054	-0.055 0.047	-0.381 0.343	-0.448 -0.311
2.	Plant height(cm)			-1.91 -0.216	0.48 0.461	0.54 0.490	0.38 0.281	0.73 0.620	-0.21 -0.026	-0.79 -0.536	0.60 0.293	-0.01 -0.002	0.58 0.389
3.	Leaf length (cm)				-0.10 0.035	-1.83 -0.278	1.13 -0.028	-0.25 0.126	1.71 0.295	2.79 0.186	-2.18 -0.127	1.77 -0.164	-0.78 0.044
4.	Leaf width(cm)					-0.202 -0.195	0.822 0.582	0.441 0.380	0.391 0.354	-0.118 0.112	1.23 0.405	0.11 0.100	0.53 0.431
5.	No of primary branches						-0.083 -0.067	0.447 0.412	-0.305 -0.247	0.627 0.577	-0.134 -0.034	0.291 0.361	0.545 0.501
6.	No of clusters per plant							0.517 0.342	0.607 0.525	-0.548 -0.151	1.159 0.336	-0.040 -0.003	0.186 0.062
7.	No of pods per plant								0.485 0.093	-0.763 -0.613	-0.181 0.036	0.341 0.321	0.617 0.537
8.	Pod length(cm)									-0.335 -0.153	0.078 -0.001	0.222 0.193	0.052 -0.024
9.	No of seeds per pod										-0.449		-0.130
											0.003	-0.312	0.203
10.	Days to maturity											-0.193 -0.441	0.078 0.145
11.	100 seed weight(g)											-0.124	0.519 0.429

Table 7: Direct and indirect effects of yield components as partitioned by path analysis

S. No.	Character	Days to 50% flowering	Plant height (cm)	Leaf length (cm)	Leaf Width (cm)	No of Primary branches	No of Cluster Per plant	No of pods per plant	Pod length (cm)	No of seeds per plant	Days to Mature	100 seed wgt (g)	GYP
1	Days to 50% Flowering	0.2120	-0.0934	-0.0127	-.1088	-0.3277	0.1160	-0.0630	0.0017	-0.1158	0.0015	-0.0580	-.4482
2.	Plant height (cm)	0.0359	-0.5515	-0.0490	0.5716	0.5849	-0.1160	0.4847	0.0488	-0.4101	-0.0165	-0.0025	0.5803
3.	Leaf length(cm)	-0.1048	1.0533	0.0257	-.1181	-1.9761	-0.3452	-0.1675	-0.3906	1.4458	0.0599	-0.2697	-.7872
4.	Leaf width(cm)	-0.0197	-0.2693	-0.0026	1.1706	-0.2187	-0.2507	0.2905	-0.0893	0.0612	-0.0338	0.0174	0.5332
5.	No. of Primary branches	-0.0643	-0.2987	-0.0470	-.2371	1.0799	0.0254	0.2944	0.0696	-0.3247	0.0037	0.0444	0.5456
6.	No. of clusters per plant	-0.0807	-0.2100	0.0291	0.9629	-0.0901	-0.3047	0.3404	-0.1387	-0.2840	-0.0318	-0.0061	0.1863
7.	No. of Pods per plant	-0.0203	-0.4066	-0.0065	0.5173	0.4836	-0.1578	0.6574	-0.1180	-0.3953	0.0050	0.0519	0.6179
8.	Pod length(cm)	-0.0016	0.1180	0.0439	0.4583	-0.3294	-0.1852	0.3191	-0.2282	-0.1739	0.0022	0.0338	0.0526
9.	No. of seeds per plant	-0.0474	0.4367	0.0717	-.1384	-0.6774	0.1672	-0.5020	0.0767	0.5177	0.0123	-0.0475	-.1302
10.	Days to maturity	-0.0118	-0.3320	-0.0561	1.4413	-0.1457	-0.3533	-0.1194	-0.0171	-0.2325	-0.0274	0.0671	0.0780
11	100 Seed weight (g)	-0.0808	0.0089	-0.0455	0.1337	0.3152	0.0123	0.2242	-0.0507	-0.1617	0.0121	0.1521	0.5197

Path Coefficient Analysis

The genotypic correlation coefficient of seed yield with its component traits was further partitioned in to direct and indirect effects. The dependent variable taken in to consideration for path analysis was seed yield per plant. Among the twelve characters analysed seven characters showed positive effect and remaining four characters showed negative effect on grain yield per plant. The highest positive direct effect on grain yield was registered by leaf width followed by number of primary branches, number of pods, number of seeds per pod, Days to 50% flowering, 100 seed weight, leaf length, plant height, number of clusters per plant, pod length and days to maturity. The direct and indirect effects of different traits are given in table 8.

Table 8: Direct and indirect effects of yield components as partitioned by path analysis

S. No.	Character	Days to 50% flowering	Plant height (cm)	Leaf length (cm)	Leaf Width (cm)	No of Primary branches	No of Cluster Per plant	No of pods per plant	Pod length (cm)	No of seeds per plant	Days to Mature	100 seed wgt (g)	GYP
1	Days to 50% Flowering	0.2120	-0.0934	-0.0127	-.1088	-0.3277	0.1160	-0.0630	0.0017	-0.1158	0.0015	-0.0580	-.4482
2.	Plant height (cm)	0.0359	-0.5515	-0.0490	0.5716	0.5849	-0.1160	0.4847	0.0488	-0.4101	-0.0165	-0.0025	0.5803
3.	Leaf length(cm)	-0.1048	1.0533	0.0257	-.1181	-1.9761	-0.3452	-0.1675	-0.3906	1.4458	0.0599	-0.2697	-.7872
4.	Leaf width(cm)	-0.0197	-0.2693	-0.0026	1.1706	-0.2187	-0.2507	0.2905	-0.0893	0.0612	-0.0338	0.0174	0.5332
5.	No. of Primary branches	-0.0643	-0.2987	-0.0470	-.2371	1.0799	0.0254	0.2944	0.0696	-0.3247	0.0037	0.0444	0.5456
6.	No. of clusters per plant	-0.0807	-0.2100	0.0291	0.9629	-0.0901	-0.3047	0.3404	-0.1387	-0.2840	-0.0318	-0.0061	0.1863
7.	No. of Pods per plant	-0.0203	-0.4066	-0.0065	0.5173	0.4836	-0.1578	0.6574	-0.1180	-0.3953	0.0050	0.0519	0.6179
8.	Pod length(cm)	-0.0016	0.1180	0.0439	0.4583	-0.3294	-0.1852	0.3191	-0.2282	-0.1739	0.0022	0.0338	0.0526
9.	No. of seeds per plant	-0.0474	0.4367	0.0717	-.1384	-0.6774	0.1672	-0.5020	0.0767	0.5177	0.0123	-0.0475	-.1302
10.	Days to maturity	-0.0118	-0.3320	-0.0561	1.4413	-0.1457	-0.3533	-0.1194	-0.0171	-0.2325	-0.0274	0.0671	0.0780
11	100 Seed weight (g)	-0.0808	0.0089	-0.0455	0.1337	0.3152	0.0123	0.2242	-0.0507	-0.1617	0.0121	0.1521	0.5197

Conclusion

The eight diverse genotypes of Black gram taken to gain an insight into the existing pattern of variability for twelve traits showed significant variation. The genotypes were grouped into different clusters. Considering all the diversity, mean performance and quantitative characters studied the genotypes MDU 1, Nirmala and VBN 9 were found to be best for yield improvement breeding programmes in Black gram.

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