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Research Article

Genetic diversity analysis in blackgram [Vigna mungo (L.) Hepper]

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Abstract
A study was conducted focusing on assessing the level of variability present among the hundred and two blackgram genotypes based on Mahalanobis’s $D^2$ statistics for nine quantitative traits. Out of eighteen clusters, the maximum inter cluster distance was observed between cluster XVI and XV. Cluster XVIII had a low mean value for days to 50% flowering, cluster XIII had a high mean value for plant height, the number of primary branches per plant and cluster XVII recorded the highest number of pods per plant. High heritability coupled with high GAM was observed for plant height, the number of primary branches per plant, the number of clusters/plants, the number of seeds per pod, hundred seed weight, protein content, and single plant yield. From the association analysis single plant yield was positively and significantly associated with the number of clusters per plant and the number of pods per plant. Hence, simultaneous selection of the above traits would be more rewarding to bring genetic improvement in black gram breeding programmes.

Key words
Blackgram, Correlation, Variability, Heritability, Genetic Diversity.

INTRODUCTION
Black gram (Vigna mungo L. Hepper), also called urdbean is a member of the Asian Vigna crop group. It is extensively used only in India and now grown in the Southern United States, West Indies, Japan and other tropics and subtropics (Delic et al., 2009). Seed yield of black gram is low, being about 450–800 kg/ha (Gupta et al., 2013). The major constraints in achieving higher productivity are lack of exploitable genetic variability, absence of suitable ideotype for different cropping systems poor harvest index, susceptibility to biotic and abiotic stresses, non-availability of quality seeds of improved varieties and narrow genetic base occur due to repeated usage of few parents with a high degree of relatedness in crossing programmes. Limited variability has been exploited in varietal development programmes in black gram (Jayamani and Sathya, 2013).

To increase the potential of a black gram as food and feed, it is necessary to study and exploit the genetic diversity of this crop. Genetic diversity is a pre-requisite for any crop improvement program as it helps in estimating and establishing genetic relationship in germplasm collection, identifying diverse parental combinations to create segregating progenies with maximum genetic variability and superior recombinations for further selection and introgressing desirable genes from diverse germplasm. The $D^2$ analysis proposed by Mahalanobis (1936) is an effective tool in quantifying the degree of genetic divergence among the genotypes. Keeping the above in view, the present study was undertaken to identify the best performing germplasm of black gram based on quantitative traits using Mahalanobis $D^2$ statistics and Tocher’s method.

MATERIALS AND METHODS
In the present study, 102 genotypes of black gram (Table 1) were evaluated at the Department of Plant Breeding and Genetics in Agricultural College and
## Table 1. Pedigree details of blackgram genotypes

| S. No. | Germplasm accessions | Pedigree | S. No. | Germplasm accessions | Pedigree |
|--------|----------------------|----------|--------|----------------------|----------|
| 1      | KU-12-668            | Selection from TU 94-2 | 26     | VBG-11-037           | ADT 5 x Vigna mungo var. silvestris |
| 2      | ABG-11-004           | VBN 1 x VBN 3-3          | 27     | IC281999             | Kolhar, Adilabad, AP |
| 3      | IC436720             | Landrace- Shimpur, Adilabad, AP | 28     | IC 431304             | Landrace- Gangwar, Medak, AP |
| 4      | VBG-12-042           | VBN 5 x COBG 757         | 29     | IC343939             | Land race |
| 5      | VBG-11-018           | VBG 73 x Vigna mungo var. silvestris | 30     | IC343885             | Land race |
| 6      | IC-436784            | Land race              | 31     | VBG-11-050           | ADT 5 x Vigna mungo var. silvestris |
| 7      | VBG-12-005           | VBN 3 x Vigna mungo var. silvestris | 32     | IC 281994             | Singango, Adilabad, AP |
| 8      | ABG-11-011           | RBU 38 x TMV 1/4/1       | 33     | IC 436758             | Land race |
| 9      | ABG-11-020           | VBN 5 x VBG 04-001       | 34     | KKB-14-011           | IPU 2006-01 x TNY local |
| 10     | IC-398989            | Landrace- Vinjamur, Nellore, AP | 35     | VBG-13-023           | VBN 5 x VBN 4 |
| 11     | VBG-12.034           | VBN 1 x KU 238          | 36     | VBG 100053           | VBN 2 x VBN 04003 |
| 12     | IPU.0233             | -                      | 37     | IC 281988             | Pochara, Adilabad, AP |
| 13     | VBG10.010            | AD 75 x Vigna mungo var. silvestris | 38     | IC 282002             | Machikal, Adilabad, AP |
| 14     | KU.12.39             | Selection from COBG 10-05 | 39     | ABG 11-030           | CO 5 x AC 196/3/3 |
| 15     | ABG.11.013           | VBN 4 x Co(Bg) 629/8/3  | 40     | IC 282007             | Narsapur, Madak, AP |
| 16     | IC281986             | Lakkapnar, Adilabad, AP | 41     | IC 281993             | Singango, Adilabad, AP |
| 17     | VBG-11-043           | AD 75 x Vigna mungo var. silvestris | 42     | VBG-14-003            | KU 216 x VBN 3 |
| 18     | KU-11-680            | Selection from IPU 99-33 | 43     | IC 282008             | Land race |
| 19     | ABG-11-028           | Co(Bg) 671 X ADT 5       | 44     | IC 281792             | Land race |
| 20     | ABG-11-032           | Co 5 x VBN 4/6/1        | 45     | VBG-11-028           | ADT 5 x Vigna mungo var. silvestris |
| 21     | ABG-11-011           | RBU 38 x TMV 1/4/1      | 46     | VBG-12-121           | VBN 3 x AM 6 |
| 22     | IC343967             | Rampachodavaram East Godavari, AP | 47     | IC 281980             | Thumkipad, Khammam, AP |
| 23     | VBG-11-044           | VBG 73 x Vignamungo var. silvestris | 48     | IC 281982             | Pashathand, Adilabad, AP |
| 24     | ADT-5                | Pure line selection from kanpur | 49     | KKB-14-001           | IPU 2006-01 x ADT 3 |
| 25     | VBG-11-046           | ADT 5 x Vignamungo var. silvestris | 50     | IC 281977             | Penpahad, Nalgonda, AP |
| 51     | VBG-14-015           | VBN 5 x PU 51           | 52     | VBG-12-122           | VBN 3 x AM 6 |
| 53     | VBG-10.045           | VBG 73 x Vignamungo var. silvestris | 78     | VBG 11024             | ADT 5xVigna mungo var. silvestris |
| 54     | VBG-11-041           | ADT5 x Vigna mungo var. silvestris | 79     | IC 436736             | Landrace-Lokari, Adilabad, AP |
| 55     | IC281987             | Kanchrapalli, Prahkasam, AP | 80     | VBG-14-013           | Selection from ACM 05 007 |
| 56     | KKB 14-003           | Chinchall, Adilabad, AP | 81     | IC 282004             | Improved cultivar- Mudhol, Adilabad, AP |
| 57     | VBG-12-122           | VBN 3 x AM 6            | 82     | VBG 10-024            | Improved cultivar- Mudhol, Adilabad, AP |
| 58     | VBG-12-039           | VBN 1 x PU 31           | 83     | VBG-11-027           | ADT 5 x Vigna mungo var. silvestris |
| 59     | IC281978             | Aathukur, Khammam,AP    | 84     | VBG-11-042           | VBG 73 x Vigna mungo var. silvestris |
| 60     | IC343724             | Lokari, Adilabad, AP    | 85     | VBG-12-093           | VBG 73 x Vigna mungo var. silvestris |
| 61     | ABG-11-035           | Co(Bg) 671 X Co(Bg) 647/3/3 | 87     | IC 281982             | Improved cultivar- Pashathand, Adilabad, AP |
| 62     | ABG-11-037           | Co(Bg) 671 x ADT 5      | 88     | IC335331             | Others- Mimilipally, Ponnur, Guntur, AP |
| 63     | VBG-11-033           | VBG 73 x Vigna mungo var. silvestris | 89     | VBG-11-029           | VBG 73 x Vigna mungo var. silvestris |
| 64     | ABG-11-015           | RBU 38 x TMV 1/1/1      | 90     | IC 281991             | Kolhar, Adilabad, AP |
| 65     | IC343943             | Others- Chandhrurthi, East Godavari, AP | 91     | ABG-11-036           | Co(Bg) 671 X Co(Bg) 647/1/4 |
| 66     | VBG-12-034           | VBN 1 x KU 238          | 92     | VBG-11-040           | VBN 1 x Vigna mungo var. silvestris |
| 67     | KKB 06-012           | VBN 5 x COBG 643        | 93     | VBG-13-019           | VBN 3 x Vigna mungo var. silvestris |
| 68     | IC436765             | Liguadora, Adilabad, AP | 94     | IC 281990             | Dallabad, Adilabad, AP |
| 69     | VBG 12062            | PU 31 x CO 6           | 95     | IC346536             | Siripuram, RangaReddy, AP |
| 70     | IC281992             | Singango, Adilabad, AP | 96     | IC349347             | Others- Seethapally, East Godavari,AP |
| 71     | IC281984             | Improved cultivar- Rolemanga, Adilabad,AP | 97     | KU-11-667             | Selection from UH 07-06 |
| 72     | VBG 13-017           | VBN 3 x Vigna mungo var. silvestris | 98     | IC 281995             | Singango, Adilabad, AP |
| 73     | IC436727             | Landrace- Lokari, Adilabad, AP | 99     | KKB-07-001           | CoBg 643 x VBN 3 |
| 74     | IC282001             | Improved cultivar- Machikal, Adilabad, AP | 100    | ADT 2 x RU 1          | |
| 75     | IC346811             | Landrace- Gottitapattar, Adilabad, AP | 101    | VBN 4                | CO 4 x PDU 102 |
| 76     | VBG-12-056           | PU 31 x CO 6           | 102    | ADT 3                | Pureline selection from Tirunelveli local |

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RESULTS AND DISCUSSION

The mean performance showed a wide range of variation for most of the characters under study. The mean performance of genotypes for days to 50 per cent flowering ranging from 30.00 (VBG 12034, VBG 10010) and to 44.50 (KKB 14011) days. The plant height recorded the mean value of 43.02 cm with a range of 22.40 cm and to 44.50 (KKB 14011) days. The plant height recorded variation for most of the characters under study. The genotypic correlation coefficient was calculated based on the formulae given by Johnson et al. (1955). The genotypic correlation coefficient was calculated based on the formulae given by Snedecor (1961).

Table 2. Mean performance of 9 characters in blackgram genotypes (KU 1239) to 59.90 cm (ABG 11036). The mean performance the mean value of 43.02 cm with a range of 22.40 cm and to 44.50 (KKB 14011) days. The plant height recorded variation for most of the characters under study. The genotypic correlation coefficient was calculated based on the formulae given by Johnson et al. (1955). The genotypic correlation coefficient was calculated based on the formulae given by Snedecor (1961).

| S. No. | Name of genotypes | Days to 50 % flowering | Plant height (cm) | Number of primary branches per plant | Number of clusters per plant | Number of pods per plant | Number of seeds per pod | 100 seed weight (g) | Single plant yield (g) | Protein content (g) |
|--------|-------------------|------------------------|------------------|-------------------------------------|----------------------------|-------------------------|----------------------|---------------------|----------------------|---------------------|
| 1      | KU 12668          | 37.50*                 | 33.50            | 5.60                                | 8.30                       | 33.20 *                 | 7.16                 | 4.36                | 7.09                 | 23.51               |
| 2      | ABG 11004         | 40.00                  | 42.30            | 6.60 *                              | 10.70 *                   | 42.80 *                 | 6.50                 | 3.54                | 10.80                | 26.91               |
| 3      | IC 436720         | 39.50                  | 48.10 *          | 5.40                                | 9.50 *                    | 28.50                   | 6.60                 | 6.56 *              | 16.40 *              | 27.71               |
| 4      | VBG 12042         | 31.50*                 | 44.20            | 5.80                                | 9.90 *                    | 29.70                   | 6.33                 | 4.80                | 16.70 *              | 22.00               |
| 5      | VBG 11018         | 34.00*                 | 46.80            | 5.80                                | 9.60 *                    | 19.20                   | 6.50                 | 4.84                | 22.70 *              | 22.27               |
| 6      | IC 436784         | 40.50                  | 51.70 *          | 6.80                                | 6.10                      | 30.50                   | 6.60                 | 3.63                | 8.15                 | 25.78*              |
| 7      | VBG 12005         | 32.50*                 | 45.80            | 7.00                                | 10.80 *                   | 43.20                   | 6.00                 | 4.32                | 9.80                 | 20.83               |
| 8      | ABG 11011         | 34.50*                 | 49.30 *          | 7.00                                | 6.40                      | 25.60                   | 7.25                 | 3.17                | 11.30                | 27.27*              |
| 9      | VBG 11020         | 34.00*                 | 36.00            | 5.80                                | 7.80                      | 31.20 *                 | 6.25                 | 4.86                | 17.87 *              | 18.99               |
| 10     | IC 398899         | 31.50*                 | 57.50 *          | 5.80                                | 11.00 *                   | 33.00 *                 | 6.70                 | 4.42                | 7.00                 | 24.51               |
| 11     | VBG 12034         | 30.00*                 | 43.00            | 5.60                                | 7.80                      | 31.20 *                 | 6.25                 | 4.54                | 11.54                | 23.48               |
| 12     | IPU 0233          | 31.50*                 | 34.00            | 5.60                                | 8.40                      | 25.20                   | 7.20                 | 4.60                | 11.00                | 24.18               |
| 13     | VBG 10010         | 30.00*                 | 29.75            | 6.20                                | 7.20                      | 36.00 *                 | 7.20                 | 4.77                | 11.34                | 20.93               |
| 14     | KU 1239           | 33.00*                 | 22.40            | 4.80                                | 6.60                      | 26.40                   | 7.00                 | 4.95                | 9.06                 | 17.80               |
| 15     | ABG 11013         | 40.00                  | 44.90 *          | 5.20                                | 5.70                      | 28.50                   | 6.40                 | 4.25                | 8.20                 | 23.93               |
| 16     | IC 281986         | 36.00*                 | 48.30            | 5.40                                | 5.70                      | 28.90                   | 7.70                 | 5.44 *              | 9.82                 | 21.53               |
| 17     | VBG 11043         | 38.50                  | 43.60            | 4.50                                | 7.90                      | 23.70                   | 6.40                 | 4.07                | 5.94                 | 22.65               |
| 18     | KU-11-680         | 37.50*                 | 25.75            | 4.80                                | 8.10                      | 40.50 *                 | 6.00                 | 4.32                | 12.98 *              | 19.58               |
| 19     | ABG 11028         | 36.00*                 | 36.70            | 4.60                                | 6.20                      | 31.00 *                 | 6.00                 | 4.60                | 10.36                | 25.80*              |
| 20     | ABG 11032         | 40.50                  | 53.30 *          | 4.80                                | 6.10                      | 30.50                   | 7.00                 | 5.54 *              | 13.05 *              | 26.79*              |
| 21     | ABG 11011         | 32.00*                 | 48.90 *          | 3.80                                | 11.00 *                   | 44.00 *                 | 6.33                 | 3.17                | 7.97                 | 27.27*              |

The trait number of primary branches per plant was 5.84 and the range varied from 3.20 (IC281978) to 11.60 (ABG 11030). The number of clusters per plant recorded the mean of 7.88 with the range of 3.20 (IC 282002) to 18.40 (IC 281982). The mean obtained for the trait number of pods per plant was 28.97 with the range varied between 15.20 (VBG 11024) and 49.60 (KU 11667). The mean obtained for the trait was 6.51 which revealed significant in 14 genotypes. The trait number of seeds per pod exhibited the minimum of 5.00 (VBG 12122, IC 281980) and the maximum 8.00 (VBG 13023) based on the mean value. The range recorded for single plant yield varied from 3.17 g (ABG 11011) to 6.60 g (IC 335331) with an average of 4.67 g and seventeen genotypes had shown significantly higher values for this trait based on the mean value. The range recorded for single plant yield varied from 4.02 g (IC 343947) to 29.10 g (IC 343962) with an average of 11.13 g and thirty-three genotypes had shown significantly higher value for this trait based on the mean value. The range recorded for protein content varied from 17.20 g (VBG 11044) to 28.44 g (ABG 11015) with an average of 23.07 g and 28 genotypes had shown significantly higher value for this trait based on the mean value. Based on overall mean performance, the genotypes IC 343885 and IC 335331 are suitable to improve the yield, and also other characters viz., the number of clusters per plant and the number of pods per plant. The genotypes KKB 14001 AND KKB 14003, IC 343885 and IC 335331 are suitable to improve the number of pods and clusters per plant. Therefore, these genotypes can be used in the future breeding programme for improving the seed yield and other characters (Table 2).
| IC   | VBG  | ADT  | VBG  | VBG  | VBG  | VBG  |
|------|------|------|------|------|------|------|
| 343967 | 11044 | 33.50* | 48.55* | 5.60 | 38.00 | 6.00 |
| 343967 | 11044 | 39.00 | 48.55* | 5.60 | 8.25 | 24.75 |
| 343967 | 11044 | 40.00 | 48.55* | 5.60 | 8.70 | 26.10 |
| 12216 | 7722 | 33.50* | 48.55* | 5.60 | 6.70 | 6.00 |
| 12216 | 7722 | 34.80 | 48.55* | 5.60 | 6.70 | 6.00 |
| 12216 | 7722 | 35.00* | 48.55* | 5.60 | 6.70 | 6.00 |
| 12216 | 7722 | 36.00* | 48.55* | 5.60 | 6.70 | 6.00 |
Genetic divergence analysis was carried out by calculating $D^2$ values from the means of 102 genotypes of black gram for nine characters. The genotypes were grouped into 18 clusters (Table 3). Among the 18 clusters, cluster 1 contains the maximum number of 50 genotypes followed by cluster II (16 No.), cluster IX (14 No.) and cluster III (8 No.). Clusters viz., IV, V, VI, VII, VIII, X, XI, XII, XIII, XIV, XV, XVI, XVII and XVIII had one genotype each. The intra and inter cluster $D^2$ values are presented in Table 4. The intra-cluster distance values ranged from

Table 3. Clustering pattern of studied genotypes in blackgram

| Cluster number | Number of genotypes | Genotypes |
|----------------|---------------------|-----------|
| I              | 50                  | IC 281986, IC 281989, IC 436758, VBG 11033, IC 281992, ABG 11013, VBG 13023, IC 281995, VBG 11043, IC 343947, ABG 11028, IC 281978, VB G 11046, VB G 11024, IC 436727, IC 343943, VB G 12039, VB G 11044, IC 436724, ABG 11015, VB G 12093, IC 436784, IC 281982, VB G 12034, IC 398970, IC 436765, VB G 12122, VB G 14013, IC 281984, VB G 11028, IC 281990, ADT 3, APK 1, IC 343967, VB G 12039, VBG 14003, VBG 11050, IC 281977, VB G 12034 |
| II             | 16                  | IC 281792, VB G 11040, IC 281991, ADT 5, VB G 11042, VB G 10024, IC 282002, VB G 12062, VB G 11020, VB G 12042, IC 281994, IC 436720, VB G 11018, IC 282001, VB G 11041, ABG 11037 |
| III            | 8                   | VB G 10010, VB G 10024, KU 11680, VB G 13019, KU 1239, VB G 11 046, VB G 13017, VB G 10053 |
| IV             | 1                   | ABG 11032 |
| V              | 1                   | VB G 11037 |
| VI             | 1                   | VB G 11045 |
| VII            | 1                   | IC 281993 |
| VIII           | 1                   | VB G 12005 |
| IX             | 14                  | IC 343885, IC 335331, IC 281999, ABG 11004, KU 11667, KKB 14011, KKB 14011, ABG 11035, IC 398989, ABG 11030, VB G 14003, VB G 11029, ABG 11036 |
| X              | 1                   | IC 436811 |
| XI             | 1                   | KKB 06012 |
| XII            | 1                   | IC 282002 |
| XIII           | 1                   | IC 281792 |
| XIV            | 1                   | IC 343962 |
| XV             | 1                   | IC 281987 |
| XVI            | 1                   | KKB 14003 |
| XVII           | 1                   | KKB 14001 |
| XVIII          | 1                   | IC 281982 |
The maximum intra cluster $D_2$ value was observed in cluster IX (23.08) followed by cluster III (19.98) and cluster II (17.95). The inter cluster distance values ranged from 15.20 to 72.84. The maximum inter cluster distance was observed between cluster XVI and XV (72.84) followed by XIV and XVI (66.07) that indicated wide divergence existed among the genotypes of these clusters. From the studies, inter cluster distance was more than the intra cluster distances. Similar results were reported by Kavani et al. (2007). The least value of inter-cluster $D_2$ value was observed in between cluster VII and XIII (15.20) suggested that the genotype in one cluster is in close proximity with the genotype in the other cluster of pair. Hence, genotypes from both clusters may not be useful in breeding programmes. This is in agreement with Kumar et al. (2015).

Table 4. Average intra (diagonal) and inter cluster (between) distance of blackgram genotypes.

| Clusters | I    | II   | III  | IV   | V    | VI   | VII  | VIII  | IX   | X    | XI   | XII  | XIII  | XIV  | XV    | XVI  | XVII  | XVIII |
|----------|------|------|------|------|------|------|------|-------|------|------|------|------|--------|------|-------|------|-------|-------|
|          | 17.34| 24.32| 25.11| 19.97| 20.02| 20.68| 20.66| 26.05 | 28.55| 20.98| 27.88| 28.80| 43.23  | 46.13| 39.11 | 33.87| 30.85 |
|          | 17.95| 29.38| 22.61| 27.46| 24.05| 25.75| 32.70| 33.24 | 34.07| 27.93| 23.10| 27.71| 27.79  | 31.34| 48.07 | 39.43| 36.60 |
|          | 19.98| 33.18| 31.15| 36.12| 36.12| 36.12| 25.68| 27.89 | 37.03| 40.19| 47.67| 48.62| 37.14  | 28.24| 37.02 |
|          | 0.00 | 22.16| 15.63| 27.49| 27.98| 45.62| 45.20| 51.44 | 39.11| 44.91| 37.11| 35.90| 38.57  |      |       |
|          | 0.00 | 9.89 | 16.22| 31.07| 25.49| 45.51| 49.03| 40.73 | 34.95| 44.87| 40.40|      |       |       |
|          | 0.00 | 21.43| 39.12| 39.28| 32.87| 24.88| 30.81| 40.91 | 38.92| 51.97| 48.47| 40.40| 34.95  |      |       |
|          | 0.00 | 18.11| 27.87| 41.43| 33.06| 48.66| 56.86| 24.32 | 22.97| 25.59|      |      |       |      |
|          | 23.08| 28.37| 30.27| 40.60| 32.23| 47.09| 55.21| 33.15 | 29.78|      |      |      |       |      |
|          | 0.00 | 21.72| 42.95| 42.07| 55.20| 58.69| 24.36| 29.94 | 25.99|      |      |      |       |      |
|          | 0.00 | 34.57| 35.25| 46.45| 51.10| 34.57| 39.24| 21.69 |      |      |      |      |       |      |
|          | 0.00 | 36.04| 43.06| 54.71| 43.01| 39.45|      |      |      |      |      |      |       |      |
|          | 0.00 | 16.28| 66.07| 55.55| 52.55|      |      |      |      |      |      |      |       |      |
|          | 0.00 | 72.84| 60.23| 60.94|      |      |      |      |      |      |      |      |       |      |
|          | 0.00 | 28.34| 31.10|      |      |      |      |      |      |      |      |      |       |      |
|          | 0.00 | 42.11|      |      |      |      |      |      |      |      |      |      |       |      |

The relative contribution of characters for genetic divergence in black gram is represented in Table 5. The maximum percentage of genetic divergence was contributed by single plant yield (30.30%) followed by the number of pods per plant (27.80%), plant height (23.14%) and the number of clusters per plant (10.02%).

The cluster mean for the nine characters studied in black gram is given in Table 6. It revealed that cluster X with one genotype (IC 436811) had the lowest mean value for days to 50% flowering and hence this genotype could be used as a source for earliness. The highest mean value for plant height (58.80 cm) was recorded in cluster XIII. The highest mean values were recorded by cluster XVIII for the number of clusters per plant (18.40); cluster XVII for the number of pods per plant (48.80); cluster XII for the number of seeds per pod (7.80); cluster X for 100 seed weight (6.44 g) and protein content (27.13); cluster XIV

Table 5. Contribution of different traits for genetic divergence in blackgram.

| Traits                           | Number of times ranked First | Contribution Percentage |
|---------------------------------|------------------------------|-------------------------|
| Days to 50% flowering           | 79                           | 1.53                    |
| Plant height                    | 1192                         | 23.14                   |
| Number of primary branches/plant| 212                          | 4.12                    |
| Number of clusters/plant        | 516                          | 10.02                   |
| Number of pods/plant            | 1432                         | 27.80                   |
| Number of seeds/ pod            | 4                            | 0.08                    |
| 100 seed weight                 | 44                           | 0.85                    |
| Single plant yield              | 1561                         | 30.30                   |
| Protein content                 | 111                          | 2.15                    |
| Total                           | 5151                         | 100.00                  |
for the trait single plant yield (29.10 g), hence crossing these genotypes would result in getting transgressive segregants.

The success of any breeding programme depends largely on the extent of genetic variability present in the base population. The variability parameters viz., GCV, PCV, heritability ($h^2$) and GAM for different characters are presented in Table 7. The highest genetic variation was observed in single plant yield (GCV 42.72 % and PCV 42.96%); the number of clusters per plant (GCV 35.45 % and PCV 35.89 %); the number of pods per plant (GCV 26.99 % and PCV 27.16 %) and the number of primary branches per plant (GCV 26.39 % and PCV 27.15 %). Similar findings had been reported by Ramya et al. (2014). Moderate PCV and GCV were observed for the traits plant height (GCV 18.09% and PCV 18.23 %); hundred seed weight (GCV 14.29% and PCV 15.91 %) and protein content (GCV 11.52% and PCV 12.05). Similar findings had been reported for the traits of plant height and hundred seed weight by Panigrahi et al. (2014). Sowmini and Jayamani (2013) reported high PCV and GCV values for the number of clusters per plant and the number of pods per plant. In the present study, high heritability estimates were observed for all the characters. High heritability was recorded for single plant yield ($98.9 \%$), the number of pods per plant ($98.7 \%$), plant height ($98.5 \%$), the number of clusters per plant ($97.6\%$), the number of primary branches per plant ($94.5 \%$), days to fifty per cent flowering ($91.4 \%$), protein content ($91.4 \%$), hundred seed weight ($80.7 \%$) and the number of seeds per pod ($69.8 \%$). High GAM was recorded for hundred seed weight (87.53 %) followed by the number of primary branches (72.14 %).

Table 6. Cluster wise mean performance for different quantitative traits in blackgram.

| Traits Cluster | Days to 50% flowering | Plant height (cm) | Number of primary branches/plant | Number of clusters/plant | Number of pods/plant | Number of seeds/pod | 100 seed weight (g) | Single plant yield (g) | Protein content (g) |
|----------------|------------------------|-------------------|----------------------------------|--------------------------|----------------------|---------------------|---------------------|------------------------|---------------------|
| I              | 36.25                  | 43.55             | 5.55                             | 7.20                     | 26.94                | 6.54                | 4.69                | 9.08                   | 22.92               |
| II             | 36.22                  | 41.85             | 5.76                             | 7.79                     | 25.37                | 6.52                | 4.81                | 17.32                  | 23.79               |
| III            | 34.31                  | 27.74             | 6.13                             | 6.59                     | 29.41                | 6.43                | 4.47                | 9.51                   | 20.71               |
| IV             | 40.50                  | 53.30             | 4.80                             | 6.10                     | 30.50                | 7.00                | 5.54                | 13.05                  | 26.79               |
| V              | 36.50                  | 49.10             | 5.60                             | 4.00                     | 16.00                | 7.10                | 5.15                | 7.16                   | 22.18               |
| VI             | 37.50                  | 43.60             | 3.80                             | 4.20                     | 16.80                | 6.33                | 3.82                | 9.82                   | 21.45               |
| VII            | 38.00                  | 54.70             | 8.60                             | 4.60                     | 23.00                | 7.10                | 4.61                | 9.70                   | 26.39               |
| VIII           | 32.50                  | 45.80             | 7.00                             | 10.80                    | 43.20                | 6.00                | 4.32                | 9.80                   | 20.83               |
| IX             | 37.61                  | 49.40             | 6.41                             | 10.88                    | 40.69                | 6.20                | 4.48                | 11.14                  | 24.29               |
| X              | 32.00                  | 36.45             | 4.80                             | 10.80                    | 32.40                | 7.50                | 6.44                | 5.15                   | 27.13               |
| XI             | 43.00                  | 41.00             | 4.30                             | 13.60                    | 24.00                | 7.30                | 4.30                | 8.20                   | 20.10               |
| XII            | 38.50                  | 52.30             | 7.80                             | 3.20                     | 16.00                | 7.80                | 6.20                | 15.90                  | 19.58               |
| XIII           | 43.50                  | 58.80             | 10.65                            | 5.20                     | 26.00                | 7.40                | 4.30                | 14.30                  | 22.14               |
| XIV            | 37.00                  | 46.40             | 5.60                             | 8.40                     | 25.20                | 6.00                | 4.53                | 29.10                  | 23.33               |
| XV             | 35.00                  | 40.20             | 3.60                             | 3.85                     | 19.25                | 6.80                | 4.56                | 29.00                  | 25.23               |
| XVI            | 34.50                  | 31.24             | 4.60                             | 15.80                    | 48.40                | 5.62                | 4.20                | 4.38                   | 21.30               |
| XVII           | 37.50                  | 29.46             | 7.80                             | 5.60                     | 48.80                | 6.80                | 4.20                | 9.30                   | 21.24               |
| XVIII          | 34.00                  | 44.70             | 8.45                             | 18.40                    | 28.00                | 6.25                | 4.00                | 7.98                   | 23.37               |
| MEAN           | 36.91                  | 43.86             | 6.18                             | 8.16                     | 28.8                 | 6.70                | 4.70                | 12.21                  | 22.93               |

Table 7. Variability parameters in blackgram.

| Character                  | PCV (%) | GCV (%) | Heritability (%) | GAM   |
|----------------------------|---------|---------|------------------|-------|
| Days to 50% flowering      | 9.47    | 9.05    | 91.40            | 17.83 |
| Plant height               | 18.23   | 18.09   | 98.50            | 36.99 |
| Number of primary branches per plant | 27.15 | 26.39 | 94.50 | 52.85 |
| Number of clusters/plant   | 35.89   | 35.45   | 97.60            | 72.14 |
| Number of pods/plant       | 27.16   | 26.99   | 98.70            | 56.24 |
| Number of seeds/pod        | 11.02   | 9.20    | 69.80            | 15.83 |
| 100 seed weight            | 15.91   | 14.29   | 80.70            | 26.46 |
| Protein content            | 42.96   | 42.72   | 98.90            | 87.53 |
| Single plant yield         | 12.05   | 11.52   | 91.40            | 22.69 |
plant (55.24%), plant height (52.85%), protein content (22.69%), the number of seeds per pod (26.46%) and single plant yield (22.69%). In the present investigation, high heritability coupled with high GAM was recorded for hundred seed weight, the number of primary branches per plant, the number of clusters/plants, plant height, protein content, the number of seeds per pod and single plant yield indicating that additive gene action is involved in the genetic control of these traits. Selection can be recorded for the improvement of these characters in the future crop improvement programme. It is in agreement with the findings of Baisakh et al. (2014) and Reddy et al. (2011) in black gram.

The genotypic correlation coefficient between different characters studied is presented in Table 8. From the intra correlation studies, seed yield per plant had a significant and positive association with the number of pods per plant and the number of pods per plant had a positive and significant association with hundred seed weight (0.348) and the number of pods per plant (0.429). A similar result was obtained by Kumar et al. (2014) and Kanimotozi et al. (2009). Days to 50% flowering had a positive and significant association with plant height (0.307); plant height had a positive and significant association with hundred seed weight (0.225) and protein content (0.210) and the number of clusters per plant had a positive and significant association with the number of pods per plant.

Table 8. Genotypic correlation coefficient in blackgram.

| Character                      | Days to 50% flowering | Plant height | Number of primary branches per plant | Number of clusters/plant | Number of pods/plant | Number of seeds/pod | 100 seed weight | Protein content | Single plant yield |
|-------------------------------|------------------------|--------------|--------------------------------------|--------------------------|----------------------|---------------------|-----------------|-----------------|------------------|
| Days to 50% flowering         | 1.000                  | 0.307*       | -0.004                               | -0.087                   | -0.012               | 0.073               | 0.007           | 0.110           | -0.020           |
| Plant height                  | 1.000                  | 0.131        | 0.048                                | 0.031                    | 0.119               | 0.225*              | 0.210*          | 0.107           |                  |
| Number of primary branches per plant | 1.000              |              |                                      | 0.089                    | 0.070               | -0.323*             | 0.032           | 0.030           | 0.348*           |
| Number of clusters/plant      | 1.000                  |              |                                      | 0.514*                   | -0.245*              | -0.135              | -0.059          | 0.438*          |                  |
| Number of pods/plant          | 1.000                  |              |                                      | 0.270*                   | -0.136              | 0.100               | 0.429*          |                  |                  |
| Number of seeds/pod           | 1.000                  |              |                                      |                          | 0.100               | -0.022              | -0.086          | 0.030           | 0.390            |
| 100 seed weight               | 1.000                  |              |                                      |                          |                     |                    | 1.000           | 0.068           |                  |
| Protein content               | 1.000                  |              |                                      |                          |                     |                    |                 | 1.000           |                  |
| Single plant yield            | 1.000                  |              |                                      |                          |                     |                    |                 |                 |                  |

(0.514). Similar findings of association were reported by Konda et al. (2008).

It is, therefore, concluded that the genotypes belonging to different clusters having high means for desired characters and with maximum inter cluster distances (clusters viz., XVI & XV and XIV & XVI respectively) could be successfully utilized in hybridization programmes. The traits viz., for hundred seed weight, the number of primary branches per plant, the number of clusters/plants, plant height, protein content, the number of seeds per pod and single plant yield registered high heritability coupled with high GAM showed that the selection efficiency is high and it is due to the presence of additive gene action. Since the trait single plant yield had a positive and significant association with the number of clusters per plant and the number of pods per plant, selection of these traits would be more valuable to bring the desired improvement in black gram breeding program.

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