Pak. J. Bot., 43(3): 1741-1746, 2011.

SELECTION INDEX BASED ON PERFORMANCE AND HYBRID VIGOUR OVER FOUR GENERATIONS AND ITS RELATIONSHIP WITH DIVERSITY IN ELEVEN CROSSES OF *VIGNA MUNGO* (L.) HEPPER

ABDUL GHAFOOR* AND MUHAMMAD ARSHAD

National Agricultural Research Centre (NARC), Islamabad, Pakistan.

Abstract

Six cultivars of blackgram *Vigna mungo* (L.) Hepper selected from genetically diverse groups based on three years evaluation under field conditions were crossed and generations were advanced accordingly. The final experiment consisting 4 generations of 11 hybrids along with their respective parents were evaluated in four replications at N.A.R.C., Islamabad, Pakistan. The source of variation was attributed to both the factors, i.e., hybrids and generations representing high proportions of the total sum of squares. Two factors gave eigen values greater than unity and these contributed 77% of the total variability. A clear response for grouping of F_1 and F_2 was observed, whereas other two generations were intermixed, although a low level of separation was observed. On the basis of performance and hybrid vigour, three hybrids; Mash 3/Mash 1, BG 9012/BG 9025 and BG 9020/Mash 1 exhibited better potential. The hybrids with high mean performance and hybrid vigour are expected to give better chance for selection to develop superior cultivars of blackgram.

Introduction

Blackgram [*Vigna mungo* (L.) Hepper] also called urdbean or mash is one of the most important summer pulses of South Asian region where it is cultivated mainly under rain fed conditions. It has been identified as a potential crop in most of the countries but its national average is one third of the potential yield (Ghafoor *et al*., 1997). Being short duration crop, it has special advantage of growing during summer (July to October) and spring (April to June) seasons as well as in inter and multiple cropping systems (Zahid *et al*., 1998). However, work on genetic information and varietal improvement of this crop has been rather limited. Blackgram is believed to have maximum genetic diversity, especially among Asian collections including India and Pakistan (Ghafoor *et al*., 2001). The phenomenon of hybrid vigour has long been discussed but the real understanding varies from crop to crop, bared on gene-action and parents involved (Jha *et al*., 1996).

Study of heterosis will help in rejecting large number of crosses in early generations and selecting only those with high potential to advance desirable segregates in subsequent generations (Shinde and Deshmukh, 1989).

Heterosis, superiority of hybrids over their mid parents, is proportional to genetic distance between their respective parents and varying degrees of hybrid vigour (Singh & Singh, 1971; Ramanujan *et al*., 1974; Ghanderi *et al*., 1979; Arora & Pandya, 1987 and Ghafoor *et al*., 2000). Even in the absence of epistasis, multiple alleles at a given locus could lead to either positive or negative heterosis (Cress, 1966). Selection of potential cross combinations should be exploited on the basis of manifestation of heterosis for varietal improvement if better diverse parents are chosen for hybridization (Aher & Dahat, 1999). Although, heterosis is exploited in most of the field crops, yet its usefulness remained unexplored in most of the legumes including blackgram mainly because of high degrees of self pollination (cleistogamous in nature) and lack of male sterile lines. Therefore, presence of heterosis can only be utilized in pulse crops for development of high yielding pure line varieties (Singh, 1971). Heterosis for seed yield and its components has been investigated by Jahagirdar, 2001; Vikas *et al*., (1999), Santha and Veluswamy, (1999), Viswanatha *et al*., (1998), Andhale *et al*., (1996), Savithramma and Latha, (1999) and Bhor *et al*., (1997) in *Vigna* spp and varying degrees of magnitude have been reported. But these results are mainly confined to F_1 only and no information is available for further generations. Therefore, eleven crosses involving six diverse parents were evaluated for heterosis from F_1 to F_4 generations for further utilization of this material and information for crop improvement.

Materials and Methods

Six genotypes viz., Mash 1, Mash 3, BG 9012, BG 9020, BG 9025 and BG 9026 were selected from diverse groups based on evaluation under field condition from 1992 to 1994 the genotypes were crossed under green house conditions during spring seasons (March to June each year) of 1994, 1995 and 1996 (Ghafoor *et al*., 1999). Segregating generations were produced from 1997 (F_1), 1998 (F_2), 1999 (F_3), and all the four breeding generations (F_1, F_2, F_3, & F_4) along with parents were grown under field conditions during summer (July) season of 2000 for investigation of breeding methodologies and hybrid vigour. The experiments were planted in a randomized complete block design (RCBD) with three replicates at the experimental field of National Agricultural Research Centre, Islamabad, Pakistan (33.40 ^{o} N and 73.07^o E). Two rows in parents and F_1 were sown keeping 35 and 10 cm spacing between and within the rows, respectively. For other generations ten rows were planted with same spacing. All the agronomic practices were adopted as recommended by Malik, (1994). Pesticides were sprayed to protect the crop from the infestation of pests especially white fly (*Bemisia tabaci* Genn.), a vector for Mungbean Yellow Mosaic Virus (MYMV). The data were recorded for plant height (cm), number of branches plant^{-1}, number of pods plant^{-1}, pod length (cm), seeds pod^{-1}, biological yield plant^{-1} (g) and grain yield (g) on ten plants sampled at random for parents and F_1 within each hybrid, whereas 30 plants in F_2 onward were sampled for data recording within each replication. Seed weight was recorded after counting 100 seeds in grams and harvest index calculated as a ratio between grain yield and biological yield that is expressed in percentage.

Hybrid vigour was calculated as percent decrease or increase in any trait over mid, better and top parents and then average of heterotic values were calculated over the generations to minimize error. High mean values and maximum heterosis over mid, better and top parents in each cross for every trait were picked up to calculate scores for each hybrid. Three top ranked values were taken accordingly, aggregated and termed as scores. Genetic diversity for 11 hybrids along with 6 parents for all the 4 generations was estimated through principal component analysis with the help of computer software "SPSS" for Windows using first two factors were plotted against the *x-y* coordinates.

*E-mail: ghafoor59pk@yahoo.com; Phone 92-51-8443715 (office); Fax 92-51-9255201

Results

Table 1 indicated significant differences and total variance was attributed towards years, parents and their interaction for all the characters. High proportion of genetic variance expressed for most of the traits by parents indicated the extent of diversity. The parents were evaluated over four years during generation enhancement but for individual parent low deviation and non-significant variation for replications except plant height indicated high magnitude of genetic purity although blackgram is highly sensitive to environmental changes. Analysis of variance for generations and hybrids showed significant differences ($p \leq 0.01$) for all the characters in case of generations, whereas for hybrids and interaction, branches were insignificant (Table 2). This source of variation and that of the generations represented high proportions of the total sum of squares.

The PCA showed that two factors gave eigen values greater than unity, whereas others were < 1, hence first two principal components were considered important in contributing variation amongst breeding material. First two components contributed 77% of the total variability (Table 3). All the variables except harvest contributed positively to PC_1: thus this component is a weighted average of the characters. Figure 1 presents distribution of eleven hybrids for four generations along with six parents that indicated a clear response for grouping based on various generations especially F_1 and F_2, whereas other two generations (F_3 and F_4) were intermixed although a low level of separation was observed, especially Mash 3/Mash 1, Mash 1/BG 9026, BG 9020/Mash 1, Mash 1/BG 9020, BG 9012/BG 9020 and BG 9025/BG 9026 for F_3 and BG 9020/Mash 3, BG 9020/Mash 1, Mash 1/BG 9020, BG 9020/BG 9012, BG 9012/BG 9020 and BG 9025/BG 9026 in F_4. All the hybrids for F_1 except Mash 1/BG 9020 were grouped in the upper right box, whereas all the populations in F_2 were in the lower half except Mash 3/BG 9026 and BG 9012/BG 9025 which were in the upper right box of the graph. All the parents were closer to coordinates with a distinction for grouping at various levels.

From mean values and hybrid vigour (over mid and better parents) of all the hybrids and generations depending upon the best values for various characters are presented in Table 4. On the basis of results when combined for average performance and hybrid vigour, three hybrids; Mash 3/Mash 1, BG 9012/BG 9025 and BG 9020/Mash 1 were observed better although later two could not perform better for F_3 (BG 9012/BG 9025) and F_3 & F_4 (BG 9020/Mash 1). Most of the traits ranked top for hybrid vigour in these three crosses. Although the hybrid, Mash 1/BG 9020 gave the best performance for one or the other character in all the four generations but this performance could not be reflected in hybrid vigour except for vegetative traits in F_3 that might be due to involvement of epistasis or non-allelic interaction involved for various characters.

To generalize the performance of various hybrids, scores were calculated for mean performance and hybrid vigour along with standard deviation for these two parameters (Fig. 2). The results presented in the Table 4 are in coordination with figure. The hybrid, BG 9020/Mash 1 gave the best average performance on the basis of pooled generations and it was followed by the hybrids Mash 3/Mash 1 and Mash 1/9020. For heterotic performance, the hybrid BG 9012/BG 9025 ranked top and followed by BG 9020/Mash 1 and Mash 3/Mash 1. The hybrids, BG 9025/Mash 1, Mash 3/BG 9026, Mash 1/BG 9026, BG 9020/Mash 3 and BG 9020/BG 9012 were suggested to exclude for further evaluation as none of these could qualify the required level of average performance or hybrids vigour. As a linear relationship was observed among various generations for performance, therefore rejection of hybrids in early generation will save time and labour. The identified hybrids with high mean performance and hybrids vigour are expected to give better chance for selection to develop superior cultivars of blackgram.

Discussion

As based on 11 hybrids over 4 generations in most of the cases high mean performance failed to express high heterotic effects that in turn did not valued for the production of tarnsgressive segregation, therefore individual crosses are required to investigate for selection purpose. Varying degrees of hybrid vigour for different crosses have been reported by various researchers in chickpea (Bakhsh *et al*., 2001), blackgram (Ghafoor *et al*., 2000) and mungbean (Aher &Dahat, 1999). In the present study transgressive segregates were observed in the later generations of hybrids, i.e., Mash 3/Mash 1, BG 9012/BG 9025 and BG 9020/Mash 1 for most of the traits. Recombination occasionally leads to the production of desirable features not found in either parent, however the best chance of success lies in selection of suitable parents (Allard 1966). Estimates of the form of genetic variation are fundamental to the identification of suitable breeding strategies that is influenced by various factors (Bailey *et al*., 1980). Presence of additive genes in the identified hybrids suggests that hybrids may provide a desirable alternative to the development of pure lines (Kunta *et al*., 1997). The yield or adaptation of the parents is not necessarily a good indicator of superior recombination because it is a complex phenomenon that is affected by a number of factors. One common parents involved in different hybrids performed inconsistently that may not necessarily be due to common additive genes although hybrid vigour and transgressive segregation are affected by a number of factors (Guillen-Portal *et al*., 2003). This is because hybrid performance often depends on complex interactions among genes and tracking back of a particular combination is even not possible involving same parents, researchers and locations.

Selection is a real art of a researcher although nature of gene-action and basic knowledge about parents help in predicting hybrid performance. For improvement of seed yield in blackgram, breeding methods, including biparental mating among selected F_2 segregants from crosses involving the parents BG 9020 and Mash 1, need special consideration (Arshad, 2004). Malhotra *et al.,* (1979) suggested that from further segregating generations of biparental populations, desirable plants can be selected and used as in other conventional breeding programme. Simultaneously, the hybrids involving the parents BG 9020 and Mash 1 may be exploited through modified diallel selective mating system (Frey 1975). By this technique, improvement in the population can effectively be made and at the same time superior segregants are provided for further improvement in blackgram.

Since the end products of a breeding programme of a strongly self pollinated crop are usually pure-lines, there is usually little scope for exploiting non-additive genetic variation (Chauhan & Singh, 1997), hence selection in appropriate early generation is to be investigated for particular hybrid for specific character that will ultimately save the time and labour involved for breeding blackgram. The magnitude of hybrid vigour in the present study was more influenced by the average performance of parents combined with genetic diversity. Grouping of hybrids by multivariate methods is of practical value to breeders of blackgram although this technique has been implied to study genetic dissimilarities among pure-lines but it gave important information in breeding material that helped in assessment of genetic diversity that could be predicted for future development.

Table 1. Mean and Standard deviation (average of parent used in F_1-F_4) along with analysis of variance for six parents involved in 11 hybrids of blackgram.

Parents	Plant height	Branches plant^{-1}	Pods plant^{-1}	Pod length	Seeds pod^{-1}	100-seed weight	Biological yield plant^{-1}	Grain yield plant^{-1}	Harvest index
Mash 1	51.6±4.76	9.3±2.92	54.8±13.8	4.6±0.21	6.1±0.63	5.2±0.23	35.3±8.29	13.7±2.78	39.5±4.12
Mash 3	40.9±5.65	10.9±3.23	52.1±12.43	4.5±0.21	5.8±0.55	4.6±0.24	26.8±6.79	11.3±2.77	44.6±7.33
BG 9012	50.1±7.63	8.5±3.78	50.4±22.16	4.4±0.25	5.9±0.59	4.9±0.25	24.6±9.89	9.3±3.80	40.5±4.14
BG 9020	48.5±5.09	9.9±2.74	46.8±16.78	4.6±0.26	6.3±0.41	4.9±0.30	34.6±11.46	10.4±2.81	38.1±6.26
BG 9025	47.6±6.51	7.7±4.13	38.2±15.78	4.6±0.19	6.1±0.43	4.5±0.27	22.9±9.12	8.3±4.13	40.7±5.55
BG 9026	43.3±5.20	9.6±2.05	44.8±9.35	4.8±0.27	6.5±0.48	4.8±0.27	23.8±5.98	9.8±2.35	41.5±4.3
MS (Replications)	98.09*	15.89	363.25	0.56	1.68	0.14	139.67	11.72	32.22
MS (Parents)	808.73**	57.93**	1697.08**	3.58**	15.02**	2.03**	1471.91**	169.47**	230.97**
MS (Year)	397.76**	157.94**	1162.54**	2.52**	11.77**	2.96**	841.02**	401.66**	130.36**
MS (PxY)	1409.80**	62.31**	829.58**	5.65**	9.33**	2.77**	760.67**	109.89**	247.34**
Error	60.48	14.43	292.40	0.45	2.04	0.10	105.55	11.71	43.95
CV (%)	16.52	40.57	35.71	6.56	10.45	6.43	36.69	32.69	16.25

* significant at p≤0.05 and ** Significant at p≤0.01
CV- Coefficient of variability

Table 2. Mean squares for nine characters evaluated for F_1 to F_4 generation of blackgram.

Source	df	Plant height	Branches plant^{-1}	Pods plant^{-1}	Pod length	Seeds pod^{-1}	100-seed weight	Biological yield plant^{-1}	Grain yield plant^{-1}	Harvest index
Replication	2	8.563	56.47	50.04	0.19	0.26	0.02	111.51	6.30	0.29
Generation	3	4099.25**	9239.84**	6458.09**	9.37**	33.97**	1.93**	23914.92**	2936.35**	846.69**
Hybrids	10	359.71**	48.24	1664.48**	0.84**	3.21**	1.27**	650.17**	56.48**	55.40**
Generation x Variety	30	161.52**	60.84	856.57*	0.49**	2.57**	0.26**	436.21**	37.65**	43.58**
Error	86	21.976	71.66	492.21	0.09	0.40	0.04	193.03	19.10	11.72
CV (%)		9.78	38.88	24.69	3.15	4.70	4.36	20.38	39.78	8.46

* Significant at p≤0.05 and **Significant at p≤0.01
CV- Coefficient of variability

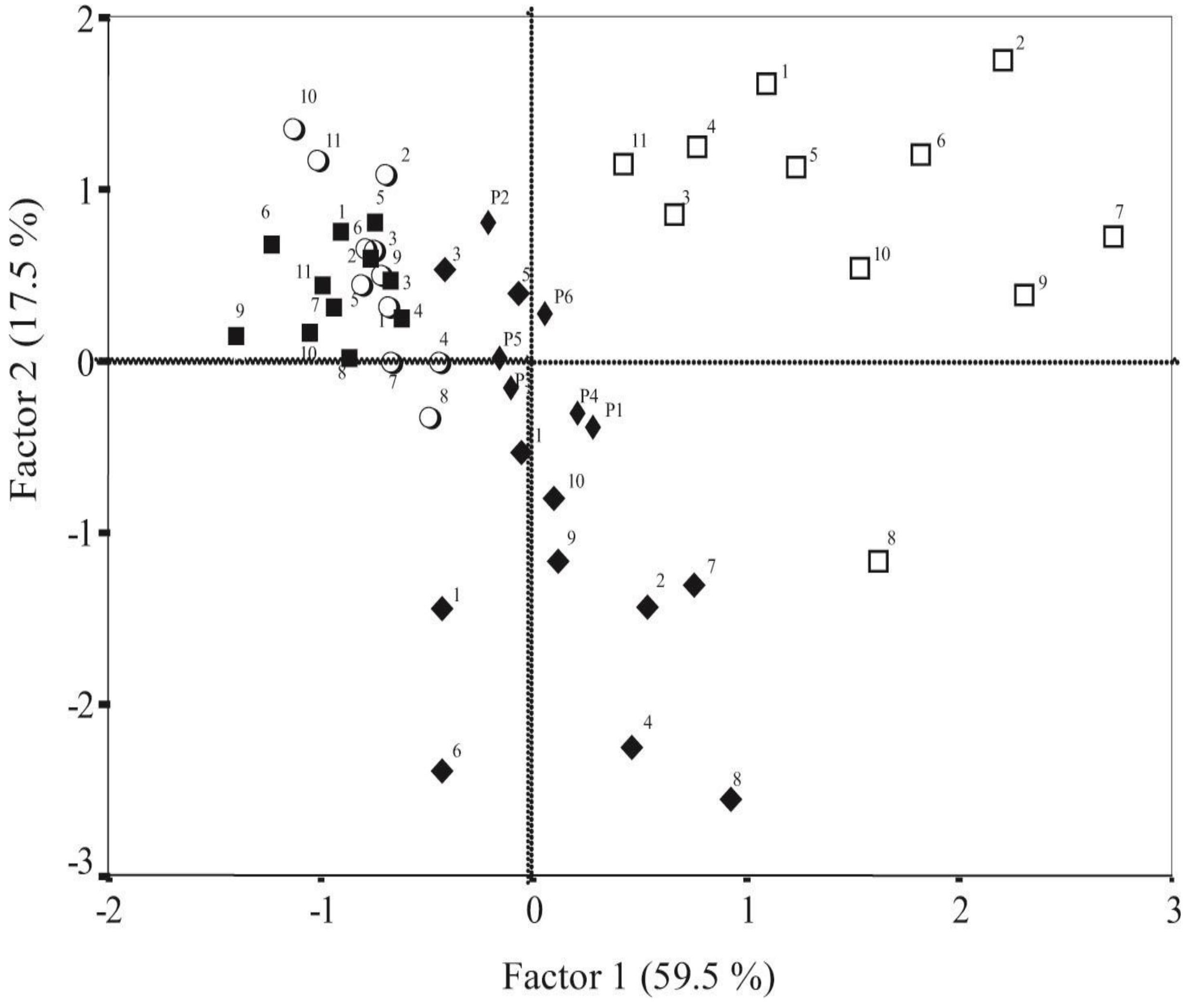

Fig. 1. Scattered diagram representing 11 hybrids evaluated for four generations based on two factors. The symbols represent as □-F_1, ♦-F_2, ○-F_3, ■-F_4, generations and ♦-parents. The hybrids are referred in Table 4.

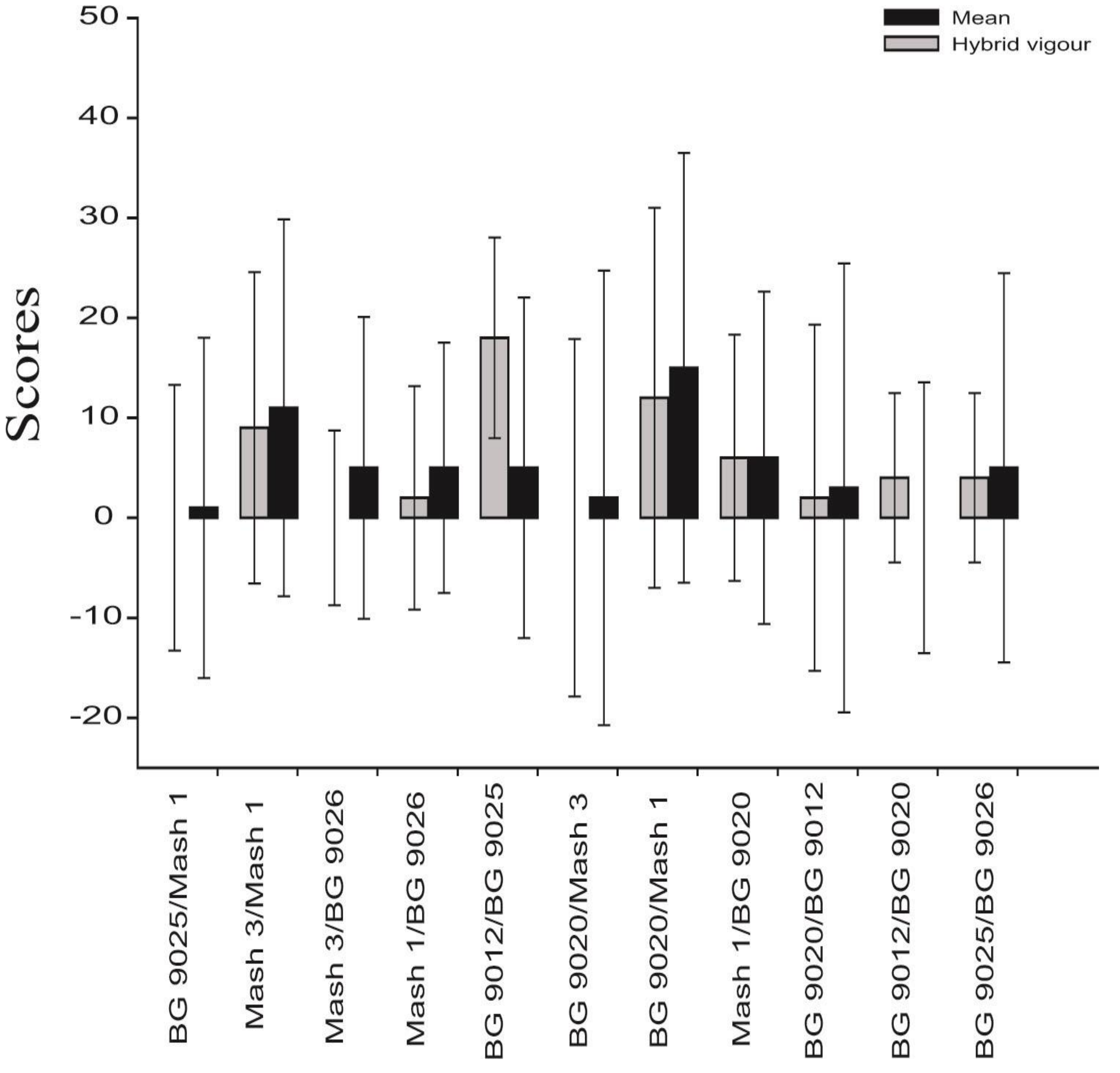

Fig. 2. Score for hybrid vigour and mean performance of 11 crosses based on four generations evaluated for nine characters.

Table 3. Principal components (PCs) for yield and its component in four segregating populations in *Vigna mungo*.

	PC_1	PC_2
Eigen value	5.4	1.5
Proportion of variance	59.5	17.5
Cumulative variance	59.5	77.0
	Factors	
Plant height (cm)	0.49	-0.77
Branches plant^{-1}	0.89	0.37
Pods plant^{-1}	0.94	0.26
Pod length plant^{-1} (cm)	0.70	0.14
Seeds pod^{-1}	0.76	0.02
Seed weight plant^{-1} (g)	0.54	-0.18
Biomass plant^{-1} (g)	0.97	0.09
Grain yield plant^{-1} (g)	0.96	0.22
Harvest index (%)	-0.64	0.67

The F_3 and F_4 generations in the same vicinity based on more that three fourth variability for 9 characters explained the similarity for these two generations, hence either generation of selected hybrids could be exploited for selection superior plant progenies. Selected hybrids from diverse groups could be used for further breeding using selective diallel mating along with hybrids identified on the basis of genetic diversity and better performance in the F_1. Variability in parents is also attributed to the variation of particular cluster involving those parents. The hybrids involving better parents from distinct clusters are likely to produce better transgressive segregates that are needed to pick up from F_3 or F_4 for breeding blackgram. Visual inspection of individual plants and unreplicated progenies of selected plants might be used as the basis of selection in segregating generations (Dahiya *et al*., 1983).

Due to high proportion of additive genes for most of the characters simple selection in large segregating population to find out better transgressive segregants might be effective for improving yield potential in blackgram (Ghafoor *et al*., 1990). On the other hand, selection for yielding ability and other characters influenced by the environment is generally postponed until later generations using single seed descent (SSD) to avoid losing desirable recombinants. As in a crop like blackgram the major emphasis is given to improve grain yield, the hybrids those gave higher values for yield and its components could be exploited for selecting superior transgressive segregates in early generations.

Table 4. Mean values, heterosis (over mid, better and top parents) ranked top three in various hybrids for four generation of blackgram.

Hybrid	Generation	Best mean performance	Best hybrid vigour		
			Mid parent	Better parents	Top parent
1. BG 9025/Mash 1	F_1	-	Br	Br	-
	F_2	-	-	-	-
	F_3	-	-	-	-
	F_4		-	-	-
2. Mash 3/Mash 1	F_1	PL	-	-	-
	F_2	Pods	PH, Br, Pods, BY	Br, Pods	Pods
	F_3	Br, Pods, BY, GY	SPP,	Br,	Br,
	F_4	BY, GY	Br, Pods, BY, GY	Br, BY, GY	Pods
3. Mash 3/ BG 9026	F_1	-	-	-	-
	F_2	HI	-	-	HI
	F_3	-	-	-	-
	F_4	SPP	SPP	SPP	-
4. Mash 1/ BG 9026	F_1	HI	-	-	HI
	F_2	-	-	-	-
	F_3	PL, SPP, 100SW	-	-	SPP
	F_4	PL	-	-	-
5. BG 9012/ BG 9025	F_1	-	PL, SPP, 100SW, GY, HI	PL, SPP, 100SW, GY HI	-
	F_2	SPP	SPP	SPP	SPP
	F_3	-	-	GY	-
	F_4	Pods	-	Pods	-
6. BG 9020/Mash 3	F_1	-	-	-	-
	F_2	-	-	-	-
	F_3	-	-	PL, SPP	-
	F_4	HI	-	-	HI
7. BG 9020/Mash 1	F_1	PH, Br, Pods, BY, GY	Pods, BY,	BY	GY, Br, Pods, BY
	F_2	GY, 100SW	100SW, GY, HI	100SW, GY, HI	100SW, GY
	F_3	-	100SW	100SW	-
	F_4	-	PL, HI	PL, HI	-
8. Mash 1/ BG 9020	F_1	100SW,	-	-	100SW
	F_2	Br, BY, PH	-	-	PH, Br, BY
	F_3	PH	PH, Br	PH, BY	-
	F_4	PH,100SW	-	-	-
9. BG 9020/ BG 9012	F_1	-	PH	Pods, PH	PH
	F_2	PL	-	-	-
	F_3	-	PL	-	-
	F_4	-	-	-	-
10. BG 9012/ BG 9020	F_1	SPP	-	-	-
	F_2	-	-	-	-
	F_3	HI	-	-	-
	F_4	-	Br	-	-
11. BG 9025/ BG 9026	F_1	-	-	-	PH
	F_2	-	PL	PL, BY	-
	F_3	-	Pods, BY, GY	Pods	-
	F_4	Br		-	Br

PH- plant height, Br-branches plant^{-1}, Pods- pods plant^{-1}, PL- pod length, SPP-seeds pod^{-1}, 100SW-100 seeds weight, BY-biological yield plant^{-1}, GY-grain yield plant^{-1} and HI-Harvest Index.

References

Aher, R.P. and D.V. Dahat. 1999. Heterosis and inbreeding depression in mungbean [*Vigna radiata* (L.) Wilczek]. *Agric. Sci. Digest Karnal*. 19(3): 155-158.

Allard, R.W. 1966. Principles of plant breeding. John Wiley and Sons, Inc. New York, London, Sydney. pp. 109-165.

Andhale, M.B. J.G. Patil and A.D. Dumbre. 1996. Heterosis and inbreeding depression studies in blackgram. *J. Maharashtra Agric. Uni*., 21(1):141-142.

Arora, P.P. and B.P. Pandya. 1987. Heterosis in chickpea, *ICN*, 16: 3-4.

Arshad, M. 2004. Inheritance of genetic traits and breeding methodologies based on various segregating generations in blackgram (*Vigna mungo* (L.) Hepper). Ph. D. Thesis. Quaid-i-Azam, Univ., Islamabad, Pakistan. pp. 225.

Bailey, T.B., C.O. Jr. Qualset and D.F. Cox. 1980. Predicting heterosis in wheat. *Crop Sci*., 20: 339-342.

Bakhsh, A., M. Arshad, A. Qureshi, A.M. Haqqani and S. Najma. 2001. Heterosis and heritability studies in chickpea (*Cicer arietinum* L.). *Pak. J. Bot*., 33: 685-690.

Bhor, T.J., N.S. Kute, A.D. Dumbre and N.D. Sarode. 1997. Heterosis and inbreeding depression studies in cowpea. *Indian J. Agric. Res*., 31(2): 122-126.

Chauhan, M.P. and I.S. Singh. 1997. Combining ability analysis for seed yield and seed size over two years in exotic and Indian crosses of lentil. *Lens Newsletter*, 24(1/2): 15-18.

Cress, C.E., 1966. Heterosis of the hybrid related to gene frequency differences between two populations. *Genetics*, 53: 269-274.

Dahiya, B.S., I.S. Solanki and K. Ram. 1983. F_2, F_3 and F_4 bulk hybrids as indicators of cross performance. *ICN*, 8: 12-13.

Frey, K.J. 1975. Breeding concept and techniques for self-pollinated crops. Bull. Int. Workshop on Grain Legumes. ICRISAT, India, pp. 257-278.

Ghafoor, A., A. Sharif, Z. Ahmad, M.A. Zahid and M.A. Rabbani. 2001. Genetic diversity in Blackgram (*Vigna mungo* L. Hepper). *Field Crops Research*, 69: 183-190.

Ghafoor, A., A.S. Qureshi and Z. Ahmad. 1999. Crossing techniques in blackgram (*Vigna mungo* L. Hepper). *Pak. J. Arid Agric*., 2(1): 25-31.

Ghafoor, A., B.A. Malik and M. Zubair. 1990. Hybrid vigour in *Vigna mungo* (L.). *Pak. J. Bot*., 22(2): 152-159.

Ghafoor, A., M.A. Zahid and M. Afzal. 1997. Status and Prospects of underutilized food legumes in Pakistan. In: Underutilized crops of Pakistan. Proceedings of 1st Int. meeting on underutilized crops of Pakistan, 28-29th May, 1997, Islamabad, Pakistan.

Ghafoor, A., Z. Ahmad, M. Afzal and A.S. Qureshi. 2000. Influence of genetic diversity and combining ability in determining hybrid vigour in blackgram {*Vigna mungo* L.). Hepper. *J. Genet. & Breed*., 54: 125-131.

Ghanderi, A., M. Shishegar, A. Rezai and B. Ehdaic. 1979. Multivariate analysis of genetic diversity for yield and its components in mungbean. J. *Am. Soc. Hortic. Sci.*, 104: 728-731.

Guillen-Portal, F.R., W.K. Russell, D.D. Baltensperger, K.M. Eskridge, N.E. D'Croz-Mason and L.A. Nelson, 2003. Best types of maize hybrids for Western high plains of the USA. *Crop Sci*., 43(6): 2065-2070.

Jahagirdar, J.E. 2001. Heterosis and combining ability studies for seed yield and yield components in mungbean. *Indian J. Pulses Res*., 14(2):141-142.

Jha, S.K., H.K. Jaiswal and A.K. Saha. 1996. Heterosis for quantitative traits in chickpea (*Cicer arietinum* L.). *J. Appl. Biol*., 6(1-2): 15-18.

Kunta, T., L.H. Edwards and R. Keim. 1997. Heterosis, inbreeding depression and combining ability in soybeans {*Glycine max* (L.) Merr.}. *SABRAO*, 29(1): 21-32.

Malhotra, R.S., P.K. Gupta and N.D. Arora. 1979. Analysis of diallel cross over environments in mungbean {*Vigna radiata* (L.). Wilczek}. *Genet. Agr*., 32: 311-322.

Malik, B.A. 1994. Grain Legume. In: *Crop Production*. (Eds.): Elina Bashir and Robyn Bantel. National Book Foundation, Islamabad, Pakistan, pp. 277-326.

Ramanujan, S., A.S. Tiwari and R.B. Mehra. 1974. Genetic divergence and hybrid performance in mungbean. *Theor. Appl*. Genet. 45: 211-214.

Santha, S. and P. Veluswamy. 1999. Heterosis for yield and yield attributes in blackgram. *J. Ecobiol*., 11(1): 65-70.

Savithramma, D. L. and J. Latha. 1999. Heterosis for yield traits in cowpea [*Vigna unguiculata* (L.) Walp]. *ACIAR Food Legume Newsletter*, 29: 7-10.

Shinde, N.V. and R.B. Deshmukh. 1989. Heterosis in urdbean. *Indian J. Pulses Res*., 2: 119-124.

Singh, K.B. and J.K. Singh. 1971. Heterosis and combining ability in blackgram. *Indian J. Genet. & Pl. Breed*., 31: 491-498.

Singh, K.B., 1971. Heterosis breeding in Pulse Crops. 4th All-India Pulse Conference Haryana Agricultural Uni., Hissar, March, 18-20. India.

Vikas, R., S. Paroda and S.P. Singh. 1999. Heterosis over environments in mungbean (*Vigna radiata* L. Wilczek). *J. Andaman Science Association*, 15(1): 12-15.

Viswanatha, K.P., Balaraju and K.K. Chakravarthy. 1998. Heterosis and inbreeding depression in cowpea, *Vigna unguiculata* (L.) Walp. *Mysore J. Agric. Sci*., 32(3): 181-185.

Zahid, M.A., R.A. Mann and Z. Shah. 1998. Overview and prospects for enhancing residual benefits in rice and wheat cropping systems in Pakistan. In: Residual effects of legumes in rice and wheat cropping systems of the Indo-Gangetic *Plain*. (Eds.): J.V.D.K. Kumar Rao, C. Johansen and T.J. Rego. Patancheru, Andhra Pradesh, India, *ICRISAT*, pp. 190-206.

(Received for publication 13 July 2009)