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Estimation of heterosis and inbreeding depression for yield and ancillary traits in Black gram (*Vigna mungo* (L.) Hepper)

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Abstract
An investigation was conducted to study the extent of heterosis over mid parent (Average heterosis), better parent (heterobeltiosis), as well as inbreeding depression in F_2 generation. A total of eight genotypes were used to generate ten crosses *viz*., LBG 20 x P 1070 (Cross I), LBG 20 x P 1053 (Cross II), LBG 752 x P 1053 (Cross III), LBG 752 x P 1070 (Cross IV), LBG 752 x TU94-2 (Cross V), MBG 207 x PU 31 (Cross VI), MBG 207 x P1053 (Cross VII), TBG 104 x P 1070 (Cross VIII), TBG 104 x PU 31 (Cross IX) and TU 68 x P 1053 (Cross X). Desirable heterosis for days to 50% flowering, days to maturity, MYMV incidence (negative) and seed yield per plant (positive) was recorded in the crosses LBG 20 x P 1070 and LBG 752 x P 1070 while most of the crosses showed inbreeding depression. The crosses, LBG 20 x P 1070 and LBG 20 x P 1053, recorded significant positive heterobeltiosis and significant negative inbreeding depression *i.e.,* less inbreeding depression for the characters viz., number of clusters per plant, number of pods per plant, leaf area and seed yield per plant. This kind of expression suggests the involvement of additive gene action in the inheritance of these traits. Therefore, the segregating material generated during the study may be utilized in identification and selection of desirable recombinants in later generations in order to develop high yielding varieties coupled with resistance to MYMV.

Keywords: heterobeltiosis, inbreeding depression, average heterosis, urdbean

Introduction
Among pulses, urdbean is an important short duration grain legume cultivated over a wide range of agro-climatic conditions. Urdbean has become the favoured choice of farmers recently times. The area under the crop has increased three times and production more than seven times since 1998-99. Urdbean received prominence in rice fallow cultivation in coastal Andhra Pradesh and Odisha, Cauvery Delta of Tamil Nadu and in certain districts of Karnataka. Major breakthrough in coastal Andhra could be possible due to development of suitable cultivars with combining resistance of powdery mildew and MYMV. However, pulses production has been stagnant between 11 to 14 million tones over last two decades. The distributing features in pulse production are poor establishment and low harvest index (Nithila and Siva Kumar 2017) [4]. The breeding approaches aimed at development and isolation of superior homozygous lines or pure line varieties in self-pollinated crop like urdbean, essentially involve identification of highly heterotic crosses and selection of superior lines in advance segregating generations. Heterosis is a valuable expression that often results from genetic recombination (Thamodharan *et al*., 2016) [7]. The exploitation of heterosis inurdbean has not been commercialized due to limited extent of out crossing. However, highly heterotic crosses can be used for development of high yielding pure line varieties in a self-pollinated crop like urdbean. Therefore, the present study was undertaken to generate information on heterosis and inbreeding depression for yield and its components in urdbean.

Materials and Methods
Eight genotypes/varieties (LBG 20, LBG 752, MBG 207, TBG 104, TU 68, P 1053, P 1070 and PU 31) were crossed to produce ten F_1's namely LBG 20 x P 1070 (Cross I), LBG 20 x P 1053 (Cross II), LBG 752 x P 1053 (Cross III), LBG 752 x P 1070 (Cross IV), LBG 752 x TU94-2 (Cross V), MBG 207 x PU 31 (Cross VI), MBG 207 x P1053 (Cross VII), TBG 104 x P 1070 (Cross VIII), TBG 104 x PU 31 (Cross IX) and TU 68 x P 1053 (Cross X) during *Rabi* 2017. The F_1's were advanced to get F_2 populations and simultaneously fresh F_1's were also made in *Kharif* 2018.

Thus, eight parents, ten F_1, and their F_2 were evaluated in during *Rabi* 2019 at Regional Agricultural Research Station, Lam, Guntur, Andhra Pradesh Seeds of parents and F_1's were sown in a single row plot, whereas, eight rows constituted a plot for F_2 each of 4 m long with a spacing of 30 cm between rows and 10 cm between plants. Observations were recorded on 5 plants from parents and F_1's and 100 plants from F_2 progenies selected randomly in each replication for ten traits *viz*., days to 50 per cent flowering, plant height, number of branches per plant, number of clusters per plant, number of pods per plant, number of seeds per pod, pod length, 100-seed weight (g), MYMV score and seed yield per plant (g).

Results and Discussion

Exploitation of heterosis is a quick and convenient way of combining desirable genes present in different parents into a single genotype. It is an indicative of producing desirable transgressive segregants for many quantitative characters in advance generations. If high heterosis is followed by low inbreeding depression indicates the presence of non-additive gene action. If the performance is same in F_1 and F_2, it shows the presence of additive genes. If the heterosis is negative in F_1 and there is increase performance in F_2 it again indicates presence of additive genes. In the present investigation heterosis of F_1 over mid parent (relative heterosis/average heterosis) and better parent (heterobeltiosis) and its component characters were estimated using the F_1's and by using the F_2 performance inbreeding depression was estimated.

1. Days to 50% Flowering

The significant positive heterosis over mid parent and better parent coupled with significant positive inbreeding depression was recorded in the crosses TBG 104 x PU 31(6.32**; 6.51**; 2.68*) and TBG 104 x P 1070 (3.09**; 4.14*; 2.16*) suggesting the operation of non additive gene effects in governing the inheritance for days to 50% flowering. Similar results of significant negative heterosis over mid parent and better parent for this trait were reported by Alle *et al*., (2014) [1], Thamodharan *et al.* (2016) [7] Suguna *et al*., (2017) [6], Shalini and Lal (2019) [5], Elangaimannan (2018) [2] and Vijay Kumar *et al*., (2017) [8]

2. Plant Height (cm)

The crosses LBG 20 x P 1053, MBG 207 x PU 31, TBG 104 x PU 31 and TU 68 x P 1053 had low inbreeding depression (-3.15, 2.19, 0.57 and -0.002) along with significant positive heterotic effects for plant height indicating the operation of additive and or additive x additive type of variance which is fixable in segregating generations. However, the cross TBG 104 x P 1070 showed low inbreeding depression along with non significant positive heterotic effects for plant height. Similar results of positive heteritic effects for plant height were also reported by Alle *et al*., (2014) [1] and Yaspal *et al*. (2015) [9].

3. Number of Branches per Plant

The crosses LBG 20 x P 1070 and LBG 20 x P 1053 recorded significant positive heterobeltiosis (9.72** and 3.83* respectively) and significant negative inbreeding depression (-24.09** and -9.02** respectively) *i.e.,* less inbreeding depression for number of branches per plant. This kind of expression suggest that the involvement of additive gene action in the inheritance of this trait. Similar kind of additive gene action was observed in case of LBG 752 x P 1070 which exhibited significant negative heterobeltiosis (-6.26*) and significant negative inbreeding depression (-5.72*) *i.e.*, less inbreeding depression. Similar kind of significant heterosis followed by low inbreeding depression for this trait was also reported by Alle *et al*., (2014) [1] and Thamodharan *et al*., (2016) [7]

4. Number of Clusters per Plant

The cross LBG 20 x P 1053 recorded higher magnitude of significant positive heterotic effects over better parent and mid parent (12.65** and 8.59*) coupled with significant positive inbreeding depression (15.03**) for number of clusters per plant, suggesting the preponderance of non additive gene action.

5. Number of Pods per Plant

The cross LBG 20 x P 1070 recorded high magnitude of heterotic effects coupled with positive non significant inbreeding depression. However, the crosses *viz.,* LBG 20 x P 1070 and LBG 20 x P 1053 additive gene action is having predominant role which can be explained by the significant positive heterobeltiosis (15.05** and 10.81** respectively) and significant positive average heterosis (17.83** and 6.04* respectively) with negligible (non-significant) inbreeding depression (2.58 and -1.24 respectively) for number of pods per plant. Significant positive heterosis over mid parent and better parent were also reported by Thamodharan *et al*., (2016) [7].

6. Pod Length (cm)

Positive significant heterotic effects with low inbreeding depression was recorded in LBG 20 x P 1070 and LBG 20 x P 1053 crosses while negative heterotic effects with low positive inbreeding depression was noticed in LBG 752 x P 1053, LBG 752 x TU 94-2, TBG 104 x P 1070, TBG 104 x PU 31crosses for pod length. Similar results were also reported by Yaspal *et al*. (2015) [9].

7. Number of Seeds per Pod

The cross LBG 20 x P 1053 manifested significant heterosis over better parent with significant positive inbreeding depression (3.09*) for number of seeds per pod suggesting the role of non additive gene action. High heterosis for this trait was also reported by Yaspal *et al.* (2015) [9].

8. 100 Seed Weight (g)

All the crosses exhibited positive heterosis over mid parent except in the cross LBG 20 x P 1070 (-10.29**). The crosses LBG 20 x P 1053 which recorded significant heterosis over better parent with less non significant inbreeding depression indicates the role of additive or additive x additive variance which are fixable in the segregating generations. Significant positive heterosis over better parent and mid parent was also reported by Yaspal *et al*. (2015) [9].

9. MYMV score

Majority of the crosses exhibited significant negative heterobeltiosis coupled with significant negative inbreeding depression confirming the role of additive or additive x additive type of gene action in the inheritance of this trait. The negative inbreeding depression may results due to segregation of genes or some times because of formation of superior gene complexes. These findings are in accordance to Thamodharan *et al*. (2016) [7].

10. Seed Yield per Plant (g)

The crosses LBG 20 x P 1053 and LBG 752 x P 1070 recorded significant positive heterosis over both parents (32.30** and 7.42** respectively) and mid parent (9.53* and 25.68** respectively) coupled with negative significant inbreeding depression (-4.54* and -5.85** respectively) indicating the role of additive and additive x additive type of gene actions in the inheritance of this trait. However non additive gene action is evident in the crosses MBG 207 x PU 31 and MBG 207 x P 1053 which are showing significant positive heterobeltiosis (4.18* and 6.19* respectively) and significant positive average heterosis (22.02** and 23.30**, respectively) coupled with negative inbreeding depression (-1.25 and -1.47 respectively). Further, it is clearly evident that non additive gene action is having greater role in inheritance of this trait from the cross LBG 20 x P 1070 which is showing significant positive heterobeltiosis and average heterosis (17.73* and 31.96** respectively). Similar kind of positive heterosis was also reported by Alle *et al*., (2014) [1], Vijay Kuar *et al*., (2017) [8], Shalini and Lal (2019) [5] and Neeraj *et al*., (2021) [3]

Table 1: Mean performance of ten characters for different generations in Black gram

S. No	Cross		Days to 50% flowering	Plant height (cm)	Branches per plant	Clusters per plant	Pods per plant	Pod length (cm)	Seeds per pod	100 seed weight (g)	YMV score	Seed yield per plant (g)
1	LBG 20 x P 1070	P_1	38.20	61.80	2.75	8.80	29.66	4.56	6.00	4.88	4.36	7.80
		P_2	37.13	60.20	2.70	5.87	28.26	4.78	6.04	4.10	1.02	6.13
		F_1	36.40	57.60	3.46	5.95	31.13	4.82	6.00	4.63	1.12	9.20
		F_2	36.37	58.79	4.29	6.69	33.35	4.79	5.80	4.70	3.12	7.95
2	LBG 20 x P 1053	P_1	38.46	61.76	2.70	8.76	28.66	4.78	5.99	4.93	4.42	7.60
		P_2	37.20	56.93	2.85	6.93	26.2	4.75	5.89	4.32	1.01	5.64
		F_1	36.40	63.40	2.88	9.02	30.4	5.21	5.64	4.96	1.11	9.42
		F_2	36.37	65.40	3.14	8.76	30.77	5.13	5.88	4.95	3.14	9.84
3	LBG 752 x P 1053	P_1	40.93	79.53	2.97	8.20	39.24	5.26	6.11	4.75	4.56	7.56
		P_2	37.53	54.06	2.98	7.76	27.71	4.99	5.79	4.44	1.02	5.39
		F_1	37.30	57.53	2.79	8.42	27.04	5.22	6.08	4.68	1.14	8.12
		F_2	37.32	75.67	2.95	7.16	27.73	5.25	6.01	4.76	3.15	8.59
4	LBG 752 x P 1070	P_1	40.53	78.73	2.59	7.72	29.76	5.20	6.16	4.75	3.27	7.06
		P_2	37.86	57.20	2.99	6.79	23.18	4.84	5.84	4.35	1.06	6.09
		F_1	36.80	69.73	2.50	7.81	24.75	5.05	6.10	4.65	1.12	6.37
		F_2	36.05	67.60	2.52	7.91	26.25	4.98	6.20	4.57	5.17	6.27
5	LBG 752 x TU94-2	P_1	40.06	59.13	2.74	7.71	31.12	5.16	6.36	4.81	4.33	8.66
		P_2	34.60	51.33	2.74	6.26	18.60	4.72	6.02	4.22	1.06	4.60
		F_1	38.33	60.13	2.49	6.34	27.24	4.76	6.10	4.71	1.14	7.45
		F_2	37.31	58.01	2.53	6.79	25.55	4.64	6.63	4.72	4.10	6.97
6	MBG 207 x PU 31	P_1	41.43	59.13	1.94	7.96	21.28	5.09	5.99	4.95	5.62	5.40
		P_2	36.00	51.33	2.83	5.16	28.29	4.49	5.99	4.48	1.07	7.63
		F_1	37.73	60.13	2.29	6.98	28.22	5.10	5.96	4.78	112	7.92
		F_2	38.45	58.81	2.12	6.55	28.86	4.98	5.87	4.73	4.20	8.15
7	MBG 207 x P1053	P_1	40.99	57.80	2.19	5.91	23.15	4.92	6.06	4.81	4.14	4.40
		P_2	37.80	55.60	3.2	7.07	26.36	4.63	5.92	4.44	1.01	6.07
		F_1	37.80	58.33	2.55	7.07	23.10	4.78	6.06	4.87	1.16	6.45
		F_2	38.26	60.72	2.52	7.24	23.37	4.81	6.00	4.71	4.14	6.56
8	TBG 104 x P 1070	P_1	35.82	59.46	4.33	6.09	33.71	5.38	6.19	5.24	1.02	8.77
		P_2	37.40	58.86	2.79	6.76	26.26	4.75	5.17	4.37	1.10	5.34
		F_1	36.73	57.20	3.54	6.08	29.06	5.10	6.07	4.83	1.15	7.55
		F_2	36.91	54.13	3.23	6.15	30.11	5.01	6.02	4.65	3.12	8.14
9	TBG 104 x PU 31	P_1	35.86	61.60	4.44	8.65	34.74	5.29	6.24	5.19	1.06	9.58
		P_2	35.73	52.43	3.41	5.86	27.88	4.99	5.94	4.43	1.05	6.17
		F_1	35.13	62.46	3.57	7.45	30.48	4.99	6.17	4.84	1.15	8.53
		F_2	37.10	62.10	3.08	7.73	31.99	4.96	5.95	4.67	3.14	8.96
		F_3	36.73	69.45	3.45	9.24	37.75	4.96	5.92	4.63	3.12	10.59
10	TU 68 x P 1053	P_1	37.60	55.33	2.45	8.68	23.20	5.00	5.96	4.54	1.09	6.96
		P_2	36.80	55.13	2.92	6.22	23.81	4.70	5.86	4.40	1.06	5.22
		F_1	36.13	61.86	2.69	7.62	23.81	4.86	6.04	4.62	1.18	6.02
		F_2	37.44	61.86	3.01	7.99	26.81	5.01	5.76	4.66	4.12	7.04

Table 2: Heterosis per cent over mid parent (RH), better parent (HB) and Inbreeding depression (ID) for ten traits in Black gram

S. No	Cross		Days to 50% flowering	Plant height (cm)	Branches per plant	Clusters per plant	Pods per plant	Pod length (cm)	Seeds per pod	100 seed weight (g)	YMV score	Seed yield per plant (g)
1	LBG 20 x P 1070	RH	-4.71**	-6.89*	9.72*	2.96	15.05**	0.97	-0.66	-17.40**	-72.22**	17.73**
		HP	-3.36	-5.67*	18.22**	14.98**	17.83**	3.35*	-0.33	-10.29**	-56.52**	31.96**
		ID	0.08	-2.06	-24.09**	2.94	2.58	0.60	1.91	-16.73**	-198.75*	13.55**
2	LBG 20 x P 1053	RH	-3.78*	16.68**	3.83*	12.65**	10.81**	6.25**	2.17	7.81*	-61.03**	32.30**
		HP	-5.37*	2.70	1.16	8.59*	6.04*	3.03*	-0.70	0.67	-75.80**	9.53*
		ID	0.24	-3.15*	-9.02	15.03**	-1.24	1.46	3.09*	0.26	-209.58**	-4.54*
3	LBG 752 x P 1053	RH	-8.79**	-15.08**	-6.26*	1.64	3.14	-0.88	-0.54	-1.54	-73.33**	7.42*
		HP	-4.84*	1.09	-6.15*	8.18*	12.84**	1.72	2.12	2.25	-58.97**	25.68**
		ID	0.03	-12.05**	-5.72*	-1.85	-2.44	-0.63	1.01	-175	-223.04**	-5.85*
4	LBG 752 x P 1070	RH	-9.21**	-6.69*	-1.57	-17.71**	-10.86**	-2.94	-0.86	-2.10	-66.66**	-9.73*
		HP	-6.12**	5.71*	1.48	-9.20*	-2.84	-0.72	1.72	2.19	-50.00**	-3.08*
		ID	2.01	3.04*	-0.62	-6.06*	-6.06*	1.41	14.72**	1.61	-344.14**	1.81
5	LBG 752 x TU94-2	RH	-4.32*	-14.40**	-9.46*	-12.47**	-12.47**	-6.60**	-4.01*	-2.07	-71.93**	-13.97**
		HP	0.17	-0.66	-2.22	6.25*	9.56*	-2.99	-1.36	4.32*	-56.16**	12.36**
		ID	1.70	0.26	-1.96	6.17*	6.17*	2.52	7.74*	-0.14	-243.35**	6.45*
6	MBG 207 x PU 31	RH	-8.26**	1.69	-19.05**	0.000	-0.25	0.26	-0.55	-3.62*	-80.00**	4.18*
		HP	-2.16	8.81*	-4.07*	8.93*	13.84**	6.53*	-0.55	1.27	-67.03**	22.02**
		ID	-1.91	2.19	7.31*	-2.39	-2.37	2.47	1.45	0.86	-208.3**	-1.25
7	MBG 207 x P1053	RH	-7.04**	0.92	-20.53**	-10.14**	-5.15*	2.97	0.00	6.13*	-79.45**	6.19*
		HP	-3.65	6.64*	5.54*	-5.44*	-2.75	0.000	1.16	4.17*	-65.90**	23.30**
		ID	-1.22	-4.10	1.08	-1.21	-1.18	-0.64	1.05	2.20	-322.08**	-1.47
8	TBG 104 x P 1070	RH	3.09*	3.81*	-18.30**	-13.86**	-13.86**	-5.20*	-1.93	-7.87*	-21.65*	-13.85**
		HP	4.14*	3.32*	-12.73**	2.71	3.78*	-2.84	3.11*	0.48	-11.76**	7.07*
		ID	2.16*	5.35*	7.79*	-3.83	-3.83*	1.76	-0.76	3.75*	-165.41**	-7.82*
9	TBG 104 x PU 31	RH	6.32*	1.10	-19.03**	-12.27**	-12.27**	-4.22*	1.06	-4.21*	-11.11*	-10.99**
		HP	6.51*	9.52**	-8.68*	2.23	2.23	-1.96	3.00*	2.10	-8.87*	8.25*
		ID	2.68*	0.57	13.53**	-4.96*	-4.97*	0.58	3.5*	3.55*	-198.04**	-5.04*
10	TU 68 x P 1053	RH	-1.77	11.80**	-7.76*	1.36	2.64	-2.66	1.34	-1.42	-6.25*	-13.41**
		HP	-0.71	12.01**	-1.46	1.99	4.63*	0.27	1.39	0.07	-3.22	-1.06
		ID	-1.39	-0.002	-11.97**	-12.40**	-9.60*	-3.02*	4.71*	-0.87	-297.91**	-16.92**

Conclusion

Nature and magnitude of heterosis and inbreeding depression varied with crosses and character. Desirable heterosis for days to 50% flowering, days to maturity, MYMV incidence (negative) and seed yield per plant (positive) was recorded in the crosses LBG 20 x P 1070 and LBG 752 x P 1070 while most of the crosses showed inbreeding depression. The crosses, LBG 20 x P 1070 and LBG 20 x P 1053, recorded significant positive heterobeltiosis and significant negative inbreeding depression *i.e.*, less inbreeding depression for the characters *viz*., number of clusters per plant, number of pods per plant and seed yield per plant. This kind of expression suggests the involvement of additive gene action in the inheritance of these traits.

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