International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(5): 2385-2390

Received: 21-07-2018
Accepted: 24-08-2018

Ranjana Patial
Department of Crop Improvement, COA, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur Himachal Pradesh, India

RK Mittal
Department of Crop Improvement, COA, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur Himachal Pradesh, India

VK Sood
Department of Crop Improvement, COA, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur Himachal Pradesh, India

Correspondence
Ranjana Patial
Department of Crop Improvement, COA, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur Himachal Pradesh, India

Estimation of heterosis for seed yield and yield contributing traits in urdbean [*Vigna mungo* (L.) Hepper]

Ranjana Patial, RK Mittal and VK Sood

Abstract
Heterosis over mid parent, better parent and standard check were determined for yield and yield components in a line x tester design among urdbean genotypes during *kharif* 2017. Twelve hybrids i.e. IC-282007 x Him Mash-1, IC-436910 x HPBU-111, IC-398956 x HPBU-111, IC-398956 x Him Mash-1, IC-413306 x Him Mash-1, IC-413305 x HPBU-111, IC-413305 x Him Mash-1, IC-281990 x HPBU-111, IC-281995 x Him Mash-1, IC-343885 x HPBU-111, IC-343943 x HPBU-111 and IC-281984 x HPBU-111 produced high heterotic effects over mid, better parent and standard check for seed yield per plant. Five cross combinations viz., IC-398956 x HPBU-111, IC-281990 x HPBU-111, IC-281995 x Him Mash-1, IC-343885 x HPBU-111, IC-343943 x HPBU-111 had shown significant and positive value over mid, better parent and standard check for seed yield per plant as well as for protein content, hence could be a good source for developing high yielding quality urdbean varieties.

Keywords: estimation, heterosis, contributing traits, urdbean, *Vigna mungo*

Introduction

The discovery of hybrid vigour by Shull (1908) [17] opened a new era in genetic improvement of crop plants which is now referred as heterosis breeding. Genetically and geographically diverse genotypes are the main pre-requisites in the development of heterotic combination (Mole *et al*. 1962) [12]. The phenomenon of heterosis has provided the one of the most important genetic tool in improving yield of self as well as cross pollinated species. Heterosis is a valuable expression that often results from genetic recombination (Lamkey and Edwards 1999) [10]. Extent and magnitude of heterosis present in hybrids is important for any crop improvement programme. In grain legumes, the heterosis is generally due to dominance gene effects but also sometimes due to epistatic interaction (Sethi 1975) [16]. In self pollinated crops, it is possible to exploit such genetic manifestation only with a potentially workable sterility mechanism, if available. A substantial component of epistatic interaction for agronomic and growth characters has been found in urdbean (black gram: *Vigna mungo*) belonging to the fixable epistasis, viz, additive x additive (Nijhawan 1975) [15]. The information regarding epistatic interaction is useful in planning a breeding program for development of pure lines with enhanced yield potential. The presence of heterosis in food legumes has also been demonstrated by Kant and Srivastava, (2012) [8]. Little information about heterosis and gene action is available in blackgram. The exploitation of heterosis in urdbean has not been commercialized due to limited extent of out crossing (Singh 2000) [18]. However, highly heterotic crosses can be used for development of high yielding pure line varieties in a self-pollinated crop like urdbean. Thus, the purpose of the present study was to determine the extent of heterosis among various cross combinations of urdbean genotypes diverse in seed yield and yield attributes.

Material and Methods

Twenty-nine genetically diverse genotypes of urdbean (*Vigna mungo* L.) were crossed in Line x Tester mating design. Twenty-seven (Lines) were used as a female (IC-281980, IC-282007, IC-282008, IC-436910, IC-281989, IC-398973, IC-281982, IC-282001, IC-398956, IC-413306, IC-413307, IC-281993, IC-343962, IC-413305, IC-398998, IC-281992, IC-413304, IC-436852, IC-282002, IC-281990, IC-281995, IC-343885, IC-343947, IC-282004, IC-

IC-413309, IC-343943 and IC-281984) and two (Testers) as male parents (HPBU-111 and Him Mash-1) to produce 54 progenies during *Kharif* 2016. These F_1 hybrids along with their parents and check i.e. Palampur-93 were evaluated in Randomized Block Design (RBD) with three replicates during *Kharif* 2017 at the Experimental Farm, Department of Crop Improvement, CSK HPKV, Palampur (HP). In each replication, entries (F_1's and parents) were grown in two rows of 1.5m length with spacing of 30 x 10 cm. The data was recorded on ten random competitive plants in each replication for all the traits viz., Plant height (cm), Branches per plant, Pods per plant, Pod length (cm), Seeds per pod, 100 seed weight (g), Biological yield per plant (g), Seed yield per plant (g), Harvest index (%), Protein content (%). The protein content (%) was determined by using macro-Kjeldhal method Jackson (1976) [7].

Estimation of heterosis

The estimates of heterosis were calculated as the deviation of F_1 mean from the mid-parent (MP), better-parent (BP) and standard check (SC)

1. Heterosis over mid-parent (MP) % $= \frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$
2. Heterosis over better-parent (BP) % $= \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$
3. Heterosis over standard check (SC) % $= \frac{\overline{F_1} - \overline{SC}}{\overline{SC}} \times 100$

Calculation of standard error

1. SE for testing heterosis over MP i.e. SE(H_1) $= \pm\sqrt{3Me/2r}$
2. SE for testing heterosis over BP i.e. SE(H_2) $= \pm\sqrt{2Me/r}$
3. SE for testing heterosis over SC i.e. SE(H_3) $= \pm\sqrt{2Me/r}$

Test of Significance for heterosis

1. Heterosis over MP $= \frac{\overline{F_1} - \overline{MP}}{SE(H_1)} =' t'$calculated
2. Heterosis over BP $= \frac{\overline{F_1} - \overline{BP}}{SE(H_2)} =' t'$calculated
3. Heterosis over SC $= \frac{\overline{F_1} - \overline{SC}}{SE(H_3)} =' t'$calculated

The 't' calculated values (t_1 and t_2) for heterosis over mid-parent (MP), better-parent (BP) and standard check (SC) were compared with 't' tabulated values at error degree of freedom and P=0.05. The 't' calculated ≥'t' tabulated values were marked significant and an asterisk (*) was put on per cent values only (Dabholkar 1992) [3].

Results and Discussion

The analysis of variance revealed significant genotypic effect for all the characters under study for parents. This provides evidence for the presence of sufficient genetic variability among lines, testers and crosses indicating wide diversity among treatment themselves (Table 1). Significance mean sum squares of females and males indicated prevalence of additive variance whereas, non-additive variance by line x tester. Variance due to interaction effect of male and female were found to be highly significant for all the traits under study except plant height, seed yield per plant, 100 seed weight and protein content. The mean square due to crosses was found to be significant for all the traits. This indicated existence of considerable amount of genetic variability among parents and hybrids for all the traits under study. The parents vs. crosses comparison was found significant for all the characters indicating substantial amount of heterosis in crosses. Similar results reported by Chakraborty *et al*. (2010) [1], Gill *et al*. (2014) [5], Thamodharan *et al*. (2017) [21].

Dwarf plant strature is desirable to develop semi-dwarf high yielding varieties. Heterotic response for this character ranged from -50.44 to 80.63 %, -60.56 to 59.46 % and -56.65 to 17.58 % over mid parent, better parent and standard check respectively (Table 2). The maximum significant negative heterosis over the over mid parent and better parent was observed for IC-282002 x Him Mash-1 (-50.44 and -60.56 %, respectively) and maximum negative heterosis over standard check was observed for IC-282008 x Him Mash-1 (-56.65 %). Similar results reported by Neog and Talukdar (1999).

Branches per plant generally associated with higher productivity. Out of 54cross combinations, twenty-six crosses showed significant positive heterosis over the mid parent, twenty crosses showed significant positive heterosis over the better parent and twenty-eight crosses showed significant positive heterosis over the standard check (Table 2). The maximum value of significant positive heterosis over the over mid parent was shown by IC-282001 x HPBU-111 (117.93 %), over better parent IC-436910 x Him Mash-1 (67.82 %) and over standard check IC-343943 x Him Mash-1 (91.36 %). Similar results reported by Natarajan and Rathanasamy (2000).

Longer pod length is associated with more number of seeds per pod resulting in higher productivity. Maximum significant heterosis over mid-parent was observed for IC-282002 x HPBU-111 i.e. 55.48 %. Maximum significant heterosis over better parent and standard check was observed for the cross IC-398956 x HPBU-111 (50.27 %) and IC-343943 x HPBU-111 (47.24%) respectively (Table 2). Heterosis for longer pod length was also reported by Sonawane and Rajendra (2015) [19].

Pods per plant are considered as one of the most important trait in yield improvement. There were thirty-six crosses which showed significant positive heterosis over mid parent, twenty-six crosses indicated significant positive heterosis over better parent and thirty-five crosses which showed significant positive heterosis over standard check. The range observed for the heterosis over mid parent was from -49.69 (IC-281980 x HPBU-111) to 96.79 % (IC-282007 x HPBU-111), over better parent was from -64.33 (IC-413307 x Him Mash-1) to 82.36 % (IC-413309 x HPBU-111) and over standard check it was from -52.66 (IC-281980 x HPBU-111) to 106.76 % (IC-282008 x HPBU-111) (Table 2). Similar results were also reported by earlier workers i.e. Vikas and Singh (1998) [24], Cheralu *et al*. (2002) [2], Gopi *et al.* (2003), Elangaimannan *et al*. (2006) [4], Zubair *et al*. (2010) [25].

Seeds per pod is one of the most important yield component. Thus, the hybrids with positive heterosis for are seeds per pod desirable for higher yields. Maximum significant heterosis manifested by cross IC-282002 x Him Mash-1 over mid-parent and better parent. Similarly, IC-398956 x HPBU-111cross had shown maximum significant heterosis over standard check (Table 3).

The range of heterosis over mid parent recorded for the trait, biological yield per plant (g) was -28.86 (IC-413307 x Him Mash-1) to 114.19 % (IC-413304 x Him Mash-1), over better parent was -55.44 (IC-413307 x Him Mash-1) to 88.94 % (IC-

282008 x HPBU-111) and over standard check was from -26.60 (IC-281989 x Him Mash-1) to 84.74 % (IC-343885 x HPBU-111) (Table 3).

For seed yield per plant, 45 cross combinations had shown significant heterosis over mid-parent. Heterotic response ranged from -66.32 to 99.34 per cent. The better-parent heterosis values ranged from -70.08 (IC-413307 x Him Mash-1) to 88.73 % (IC-413305 x HPBU-111) with 24 four cross combinations had a positive value and fifteen had negative value. The estimates of significant values of standard heterosis ranged from -76.87 (IC-281980 x HPBU-111) to 80.31 % (IC-413306 x Him Mash-1) (Table 3). There was ten cross combinations that showed significant positive heterosis over the standard check. Significant positive heterosis for seed yield per plant (g) have been reported by many researchers, some of them are Vaithiyalingan (2004), Elangaimannan *et al*. (2006) [4], Thangavel (2010) [22], Sujatha *et al*. (2011) [20], Kant and Srivastava (2012) [8], Karande *et al*. (2013) [9].

Harvest index is a trait that indicates the physiological efficiency of plant in the conversion of vegetative biomass into grain yield. IC-413306 x Him Mash-1 cross combination had shown significant positive values (16.35%, 14.69%, 28.08%) for all the three estimates of selection i.e. mid parent, better parent and standard heterosis, respectively (Table 4).

For 100 seed weight, nine cross combinations viz., IC-282007 x HPBU-111, IC-282001 x HPBU-111, IC-413307 x HPBU-111, IC-413304 x HPBU-111, IC-282002 x HPBU-111, IC-281995 x HPBU-111, IC-343885 x HPBU-111, IC- 413309 x HPBU-111 and IC-281984 x HPBU-111 had shown significant and positive values over mid parent, better parent and standard check (Table 4).

Protein content is an important quality trait for human food. The mid-parent heterosis values ranged from -12.10 (IC-398998 x Him Mash-1) to 21.49 % (IC-343943 x HPBU-111). The better-parent heterosis values ranged from -16.12 (IC-398998 x Him Mash-1) to 20.89 % (IC-343943 x HPBU-111). The values for standard heterosis ranged from -8.62 (IC-436852 x HPBU-111) to 13.24% (IC-343885 x HPBU-111) (Table 4).

Table 1: Analysis of variance in Line x Tester analysis for ten characters of urdbean

		Mean squares							
Source of variation→		**Replication**	**Parent**	**Lines**	**Testers**	**Lines vs Testers**	**Crosses**	**Parents vs. Crosses**	**Error**
Traits ↓	df→	2	28	26	1	1	53	1	164
Plant height (cm)		2.62	96.26*	103.36*	6.96	0.86	73.72*	153.48*	5.10
Branches per plant		0.30	4.87*	5.20*	0.02	1.14*	6.73*	11.66*	0.16
Pod length (cm)		0.09	1.06*	1.01*	0.01	3.54*	1.55*	0.57*	0.11
Pods per plant		0.65	281.19*	286.38*	0.75	426.83*	125.78*	164.41*	5.50
Seeds per pod		0.11	0.76*	0.59*	1.90*	4.19*	0.85*	0.73*	0.08
Biological yield per plant (g)		0.38	167.01*	160.03*	0.71	514.88*	55.35*	94.44*	2.80
Seed yield per plant (g)		0.06	2.65*	2.84*	0.29*	0.09	2.94*	21.70*	0.03
Harvest index (%)		4.42	55.72*	36.81*	15.49*	587.66*	36.22*	198.81*	1.49
100 seed weight (g)		0.01	0.89*	0.73*	5.82*	0.17	1.17*	7.11*	0.06
Protein content (%)		1.66	5.54*	5.67*	5.70	2.23	8.12*	7.33*	1.61

*Significant at 5% level of significance

Table 2: Estimates of heterosis over mid parent, better parent and standard check for different traits

Traits →	**Plant height (cm)**			**Branches per plant**			**Pod Length (cm)**			**Pods per plant**		
Crosses ↓	**H1**	**H2**	**H3**	**H1**	**H2**	**H3**	**H1**	**H2**	**H3**	**H1**	**H2**	**H3**
IC-281980 x HPBU-111	-17.81	-25.34*	-44.45**	-56.59**	-68.97**	-66.96**	25.56**	17.86**	17.86**	-49.69**	-57.23**	-52.66**
IC-281980 x Him Mash-1	42.97**	38.34**	2.93	88.62**	33.33**	47.40**	6.61	-1.02	-1.02	-25.72*	-38.39**	-31.80*
IC-282007 x HPBU-111	-15.90	-29.09**	-37.21**	-30.12*	-46.30**	-42.82**	-8.47	-12.96*	-15.34**	96.79**	71.83**	78.45**
IC-282007 x Him Mash-1	-9.48	-19.17*	-28.43**	81.82**	37.93**	52.48**	7.68	1.26	-1.50	85.90**	58.23**	64.33**
IC-282008 x HPBU-111	53.98**	46.60**	-10.91	64.44**	45.11**	54.51**	5.95	-1.21	0.20	79.45**	35.19**	106.76**
IC-282008 x Him Mash-1	-30.38**	-37.70**	-56.65**	-21.91	-32.18**	-25.03*	5.06	-3.09	-1.70	13.76	-15.99	28.48*
IC-436910 x HPBU-111	45.71**	45.61**	-11.51	76.59**	61.10**	71.54**	18.19**	8.51	13.84*	7.05	-31.88**	93.56**
IC-436910 x Him Mash-1	39.23**	30.34**	-9.31	87.06**	67.82**	85.51**	25.61**	14.10**	19.70**	-22.59**	-51.36**	38.21**
IC-281989 x HPBU-111	51.27**	29.39*	-21.37**	97.12**	46.78**	56.29**	25.70**	20.88**	14.86**	61.46**	18.74*	95.46**
IC-281989 x Him Mash-1	49.41**	21.09	-15.75*	75.00**	28.74*	42.31**	3.51	-1.58	-6.48	70.64**	23.12**	102.67**
IC-398973 x HPBU-111	80.63**	59.46**	-3.10	84.71**	45.58**	55.02**	17.31**	16.39**	2.11	81.36**	41.78**	94.98**
IC-398973 x Him Mash-1	73.41**	44.68**	0.67	93.64**	50.57**	66.45**	24.33**	23.84**	6.95	37.75**	5.40	44.95**
IC-281982 x HPBU-111	67.50**	33.23**	-19.03*	46.31**	42.12**	51.33**	19.18**	14.06*	9.48	41.00*	13.78	-11.82
IC-281982 x Him Mash-1	-13.52	-34.45**	-54.39**	-67.47**	-68.97**	-65.69**	1.01	-4.40	-8.25	92.18**	58.77**	15.80
IC-282001 x HPBU-111	53.41**	32.11*	-19.72*	117.93**	47.97**	57.56**	-13.36**	-21.23**	-15.54**	87.90**	55.17**	84.56**
IC-282001 x Him Mash-1	-1.75	-19.89	-44.26**	100.85**	35.06**	49.30**	0.14	-9.92	-3.41	-15.63	-31.95**	-19.05
IC-398956 x HPBU-111	11.18	6.00	-28.96**	4.38	-12.51	37.74**	51.21**	50.27**	31.83**	5.76	-24.83**	38.21**
IC-398956 x Him Mash-1	12.46	10.39	-23.19**	33.71**	13.80	79.16**	13.53*	12.90*	-2.18	31.78**	-7.97	69.21**
IC-413306 x HPBU-111	10.09	8.32	-31.99**	25.65*	9.90	17.03	-1.74	-17.09**	5.79	-32.40**	-52.95**	-7.02
IC-413306 x Him Mash-1	57.00**	49.34**	3.91	54.61**	33.10**	47.14**	0.03	-16.40**	6.68	39.05**	-4.82	88.09**
IC-413307 x HPBU-111	64.05**	46.11**	-11.21	83.11**	50.12**	59.85**	-14.87**	-24.55**	-14.31*	-8.39	-42.46**	74.10**
IC-413307 x Him Mash-1	15.99	-2.43	-32.11**	-65.86**	-72.41**	-69.50**	14.13**	0.12	13.70*	-42.51**	-64.33**	7.94
IC-281993 x HPBU-111	7.25	-5.60	-24.56**	62.00**	31.26**	39.77**	-15.80**	-25.42**	-15.20**	23.24	8.70	10.27
IC-281993 x Him Mash-1	29.82**	21.43*	-2.96	100.00**	59.77**	76.62**	21.03**	6.12	20.65**	94.67**	67.32**	69.73**
IC-343962 x HPBU-111	-20.68**	-39.82**	-29.30**	-57.65**	-68.97**	-66.96**	9.15	-4.28	11.38*	57.46**	49.22**	29.17*
IC-343962 x Him Mash-1	-0.78	-21.01**	-7.20	-63.49**	-73.56**	-70.78**	1.55	-11.83*	2.59	62.26**	49.49**	29.41*
IC-413305 x HPBU-111	-2.07	-22.23**	-19.66*	-9.00	-21.69*	15.63	0.92	-12.75**	4.98	66.38**	29.89**	79.33**

IC-413305 x Him Mash-1	36.02**	13.82	17.58*	-17.32*	-27.71**	6.73	-3.04	-17.00**	-0.14	91.23**	46.13**	101.74**
IC-398998 x HPBU-111	34.12**	12.88	0.40	-82.95**	-86.78**	-74.46**	-6.47	-20.20**	-0.89	30.66**	-2.70	54.12**
IC-398998 x Him Mash-1	45.93**	30.05**	15.67*	-83.26**	-86.84**	-74.59**	-14.52**	-27.77**	-10.29	18.48*	-13.48	37.05**
IC-281992 x HPBU-111	-20.45	-22.19	-52.71**	-51.81**	-61.81**	-59.34**	1.10	-4.62	-5.66	63.23**	47.40**	41.72**
Traits →	**Plant height (cm)**			**Branches per plant**			**Pod Length (cm)**			**Pods per plant**		
Crosses ↓	**H1**	**H2**	**H3**	**H1**	**H2**	**H3**	**H1**	**H2**	**H3**	**H1**	**H2**	**H3**
IC-281992 x Him Mash-1	-31.64**	-37.27**	-56.35**	-86.76**	-89.66**	-88.56**	3.10	-3.79	-4.84	-8.61	-19.64	-22.73
IC-413304 x HPBU-111	2.02	-19.61	-51.15**	-50.43**	-72.55**	-70.78**	-1.19	-7.92	-6.48	-7.22	-16.17	-35.03**
IC-413304 x Him Mash-1	-16.53	-37.27**	-56.35**	-39.58*	-66.67**	-63.15**	-4.40	-11.88*	-10.50	77.57**	64.94**	20.30
IC-436852 x HPBU-111	28.81*	10.66	-32.75**	97.39**	62.29**	72.81**	3.82	-0.64	-4.64	79.56**	69.33**	31.24*
IC-436852 x Him Mash-1	-7.92	-25.08*	-47.87**	-65.96**	-72.41**	-69.50**	1.99	-3.48	-7.36	38.89*	34.83*	-1.66
IC-282002 x HPBU-111	-35.61**	-51.17**	-42.58**	23.83**	-3.59	84.24**	55.48**	48.10**	43.56**	46.92**	22.83*	41.66**
IC-282002 x Him Mash-1	-50.44**	-60.56**	-53.63**	-8.42	-27.73**	38.12**	-3.92	-9.49	-12.27*	8.84	-11.16	2.45
IC-281990 x HPBU-111	14.22	-3.58	-14.86	-18.89	-31.86**	-27.45*	1.23	-2.86	-7.29	30.27**	-11.75*	92.74**
IC-281990 x Him Mash-1	17.04*	4.63	-7.61	-54.72**	-62.53**	-58.58**	7.72	2.21	-2.45	-10.85	-40.54**	29.86*
IC-281995 x HPBU-111	-22.71*	-22.95	-53.18**	-56.92**	-64.32**	-62.01**	40.38**	39.89**	23.59**	2.74	-18.29	7.23
IC-281995 x Him Mash-1	5.62	-1.35	-31.36**	87.61**	53.10**	69.25**	41.09**	38.97**	22.77**	95.30**	51.92**	99.38**
IC-343885 x HPBU-111	26.28**	3.93	-2.24	68.33**	60.00**	89.07**	40.78**	35.19**	28.83**	77.56**	35.17**	100.50**
IC-343885 x Him Mash-1	-44.79**	-51.98**	-54.83**	-46.22**	-47.96**	-38.50**	8.17	2.72	-2.11	42.97**	6.63	58.17**
IC-343947 x HPBU-111	-11.58	-20.06	-51.42**	33.82*	-12.89	-7.24	-4.59	-7.51	-13.57*	36.87*	25.92	-2.41
IC-343947 x Him Mash-1	14.21	-2.59	-32.22**	83.44**	18.39	30.88*	40.87**	35.01**	26.18**	73.49**	64.17**	19.74
IC-282004 x HPBU-111	-24.02*	-27.91*	-56.19**	-7.21	-13.96	-8.39	15.44**	-2.21	23.59**	6.38	3.35	-15.07
IC-282004 x Him Mash-1	-12.08	-21.58*	-45.43**	-30.64**	-36.78**	-30.11*	-8.78	-23.46**	-3.27	69.85**	60.31**	31.73*
IC-413309 x HPBU-111	26.40*	15.71	-29.68**	-14.82	-31.34**	19.44	6.39	1.41	-1.84	91.29**	82.36**	41.33**
IC-413309 x Him Mash-1	21.49	4.82	-27.07**	19.25*	-2.48	69.63**	10.72*	4.37	1.02	71.83**	68.68**	23.04
IC-343943 x HPBU-111	15.14	-2.27	-14.86	-6.02	-22.07**	26.05*	52.65**	39.99**	47.24**	50.91**	29.64*	39.91**
IC-343943 x Him Mash-1	-21.55*	-29.44**	-38.53**	40.55**	18.30*	91.36**	3.50	-6.09	-1.23	-22.29	-34.89**	-29.73*
IC-281984 x HPBU-111	40.85**	28.07*	-22.17**	8.81	0.00	27.06*	1.00	-3.14	-7.43	63.74**	45.16**	45.53**
IC-281984 x Him Mash-1	42.70**	22.36*	-14.86	-30.48**	-35.00**	-17.41	9.36	3.71	-0.89	85.28**	60.04**	60.45**
SE±	1.60	1.84	1.84	0.28	0.33	0.33	0.23	0.27	0.27	1.66	1.91	1.91

*, ** Significant at P ≤ 0.05 & P ≤ 0.01; respectively H1- heterosis over mid-parent, H2= heterosis over better-parent, H3- Heterosis over standard check i.e. Palampur-93

Table 3: Estimates of heterosis over mid parent, better parent and standard check for different traits

Traits →	**Seeds per pod**			**Biological yield per plant (g)**			**Seed yield per plant (g)**		
Crosses ↓	**H1**	**H2**	**H3**	**H1**	**H2**	**H3**	**H1**	**H2**	**H3**
IC-281980 x HPBU-111	-2.91	-6.80	8.64	0.84	-14.09	-26.23**	-66.32**	-69.00**	-76.87**
IC-281980 x Him Mash-1	19.08**	0.61	17.29**	14.02	-5.63	-18.97*	-52.78**	-54.25**	-71.29**
IC-282007 x HPBU-111	4.36	0.07	7.30	79.34**	49.62**	35.25**	63.95**	13.51	-15.30**
IC-282007 x Him Mash-1	19.73**	8.78	7.06	70.84**	38.60**	25.29**	88.08**	39.92**	-17.67**
IC-282008 x HPBU-111	16.99**	16.30**	26.17**	96.84**	88.94**	24.16**	49.32**	22.26**	-8.78
IC-282008 x Him Mash-1	9.74	-4.46	3.65	53.00**	42.00**	-6.68	9.25	-1.21	-41.87**
IC-436910 x HPBU-111	13.24**	9.97*	25.14**	98.10**	81.23**	32.01**	92.25**	53.74**	14.71**
IC-436910 x Him Mash-1	38.75**	18.40**	34.73**	66.72**	47.76**	7.63	9.97	-3.23	-43.06**
IC-281989 x HPBU-111	5.97	1.78	9.12	18.98*	-3.02	-6.99	-16.97*	-26.87**	-45.43**
IC-281989 x Him Mash-1	19.79**	8.67	7.30	-3.53	-23.47**	-26.60**	-29.03**	-30.24**	-58.96**
IC-398973 x HPBU-111	11.79**	11.01*	20.70**	6.48	-28.49**	25.93**	-23.19**	-24.96**	-44.01**
IC-398973 x Him Mash-1	7.34	-6.64	1.51	-4.77	-37.17**	10.65	-48.36**	-52.83**	-66.43**
IC-281982 x HPBU-111	-10.66**	-16.74**	3.33	54.98**	28.81**	17.56*	-0.24	-34.50**	-51.13**
IC-281982 x Him Mash-1	3.37	-14.82**	5.71	45.85**	17.89	7.59	91.92**	34.07**	-21.12**
IC-282001 x HPBU-111	28.83**	28.46**	38.54**	31.82**	23.43	-14.52	20.23**	-0.32	-25.62**
IC-282001 x Him Mash-1	15.67**	0.96	8.88	26.51*	14.65	-20.60*	-21.98*	-28.43**	-57.89**
IC-398956 x HPBU-111	22.98**	9.83*	49.80**	68.65**	43.95**	23.05**	49.13**	41.95**	17.20**
IC-398956 x Him Mash-1	12.51**	-10.58**	21.97**	99.35**	65.28**	41.29**	96.31**	68.10**	38.79**
IC-413306 x HPBU-111	6.39	-1.57	24.11**	7.09	-17.99*	-6.76	27.02**	2.33	24.91**
IC-413306 x Him Mash-1	19.20**	-2.39	23.08**	71.64**	28.30**	45.86**	99.34**	47.72**	80.31**
IC-413307 x HPBU-111	-14.71**	-17.23**	-11.26*	-11.88*	-43.98**	24.72**	-20.94**	-42.41**	-5.93
IC-413307 x Him Mash-1	12.77*	1.34	2.22	-28.86**	-55.44**	-0.79	-56.01**	-70.08**	-51.13**
IC-281993 x HPBU-111	1.99	1.84	9.52	20.32*	-5.66	0.36	-7.16	-25.76**	-44.60**
IC-281993 x Him Mash-1	38.65**	21.17**	30.29**	88.32**	43.96**	53.15**	76.17**	55.04**	-8.78
IC-343962 x HPBU-111	29.00**	23.37**	32.28**	70.80**	33.10**	44.03**	35.35**	6.84	-20.28**
IC-343962 x Him Mash-1	36.39**	24.23**	21.57**	56.84**	19.20*	28.99**	80.23**	56.25**	-8.07
IC-413305 x HPBU-111	10.91**	2.58	29.42**	32.68**	-5.66	35.11**	97.73**	88.73**	54.92**
IC-413305 x Him Mash-1	12.32**	-8.05	16.02**	58.66**	10.50	58.26**	97.81**	69.80**	39.38**
IC-398998 x HPBU-111	2.66	1.00	11.90*	32.23**	-8.07	42.28**	30.50**	22.10**	-8.90
IC-398998 x Him Mash-1	30.15**	12.31*	24.43**	16.52*	-20.55**	22.95**	18.58*	12.96	-26.57**
IC-281992 x HPBU-111	-14.74**	-19.07**	-3.41	37.22**	5.23	19.17*	25.62**	0.95	-24.67**
IC-281992 x Him Mash-1	4.49	-12.56**	4.36	-1.21	-26.06**	-16.27	6.38	-5.85	-44.60**
Traits→	**Seeds per pod**			**Biological yield per plant (g)**			**Seed yield per plant (g)**		

Crosses ↓	H1	H2	H3	H1	H2	H3	H1	H2	H3
IC-413304 x HPBU-111	-10.34*	-13.74**	0.08	16.83	5.26	-20.68*	-2.02	-34.50**	-51.13**
IC-413304 x Him Mash-1	12.80**	-4.51	10.79*	114.19**	87.07**	40.97**	96.61**	40.32**	-17.44**
IC-436852 x HPBU-111	7.17	1.59	21.57**	89.39**	58.91**	41.63**	43.74**	-0.48	-25.74**
IC-436852 x Him Mash-1	-2.58	-18.56**	-2.54	48.96**	21.50*	8.29	26.56*	-5.85	-44.60**
IC-282002 x HPBU-111	33.05**	27.29**	36.48**	78.21**	40.87**	46.55**	75.12**	43.24**	6.88
IC-282002 x Him Mash-1	55.00**	41.13**	38.22**	15.47	-11.03	-7.45	10.04	-0.60	-41.52**
IC-281990 x HPBU-111	-3.26	-4.14	4.68	20.62**	-20.98**	53.94**	23.16**	-4.08	28.35**
IC-281990 x Him Mash-1	19.70**	3.92	13.48*	-2.21	-36.98**	22.77**	-11.45*	-36.26**	-14.71**
IC-281995 x HPBU-111	2.34	-5.57	19.75**	12.72	-22.54**	25.07**	14.49*	14.31*	-14.71**
IC-281995 x Him Mash-1	2.49	-16.26**	6.19	55.38**	4.76	69.16**	91.10**	71.13**	27.28**
IC-343885 x HPBU-111	14.82**	12.31*	25.93**	74.17**	21.78**	84.74**	93.08**	79.73**	55.63**
IC-343885 x Him Mash-1	1.40	-12.94**	-2.38	35.64**	-7.02	41.05**	51.55**	27.26**	10.20
IC-343947 x HPBU-111	-13.35**	-19.53**	0.63	23.28*	0.91	-4.27	1.17	-24.64**	-43.77**
IC-343947 x Him Mash-1	21.03**	-0.57	24.35**	70.45**	35.78**	28.81**	92.29**	55.85**	-8.30
IC-282004 x HPBU-111	8.21*	-0.37	26.96**	33.70**	17.45	-6.22	-14.75	-29.73**	-47.57**
IC-282004 x Him Mash-1	5.61	-13.88**	9.75	78.67**	52.29**	21.60*	29.87**	18.35*	-30.37**
IC-413309 x HPBU-111	-2.24	-8.51	12.53*	56.99**	18.04*	41.61**	83.12**	22.42**	-8.66
IC-413309 x Him Mash-1	13.29**	-6.32	15.23**	-2.10	-28.09**	-13.73	30.79**	-6.65	-45.08**
IC-343943 x HPBU-111	9.36*	6.93	19.98**	13.80*	-26.09**	49.41**	73.61**	55.40**	46.74**
IC-343943 x Him Mash-1	28.86**	10.60*	24.11**	5.29	-32.70**	36.04**	26.32**	2.51	-3.20
IC-281984 x HPBU-111	-3.98	-8.28	8.01	102.17**	84.89**	34.79**	92.53**	55.64**	16.13**
IC-281984 x Him Mash-1	23.33**	3.77	22.20**	74.59**	54.68**	12.76	70.14**	51.61**	-10.79*
SE±	0.20	0.23	0.23	1.18	1.37	1.37	0.13	0.15	0.15

*, ** Significant at P ≤ 0.05 & P ≤ 0.01; respectively H1- heterosis over mid-parent, H2= heterosis over better-parent, H3- Heterosis over standard check i.e. Palampur-93

Table 4: Estimates of heterosis over mid parent, better parent and standard check for different traits

Traits→	Harvest index (%)			100 seed weight (g)			Protein content (%)		
Crosses ↓	H1	H2	H3	H1	H2	H3	H1	H2	H3
IC-281980 x HPBU-111	-68.08**	-74.50**	-67.34**	-11.69**	-17.69**	-13.39**	5.53	3.84	-1.00
IC-281980 x Him Mash-1	-58.95**	-65.00**	-62.03**	3.47	-9.15*	26.45**	7.46	4.37	5.59
IC-282007 x HPBU-111	-19.09**	-49.17**	-34.88**	33.11**	24.30**	30.29**	-0.08	-3.48	-4.42
IC-282007 x Him Mash-1	-3.74	-37.29**	-31.97**	-11.94**	-22.82**	7.43	1.74	0.66	1.84
IC-282008 x HPBU-111	-24.67**	-40.57**	-23.87**	-0.78	-12.53**	4.24	1.85	0.32	-4.54
IC-282008 x Him Mash-1	-29.30**	-40.54**	-35.49**	4.01	-3.46	34.37**	-2.95	-5.84	-4.74
IC-436910 x HPBU-111	-6.72	-29.67**	-9.91	19.79**	4.40	27.76**	12.45**	4.24	12.64**
IC-436910 x Him Mash-1	-36.35**	-49.09**	-44.77**	-13.05**	-18.30**	13.71**	5.54	2.18	10.41*
IC-281989 x HPBU-111	-35.36**	-52.15**	-38.71**	20.88**	2.23	34.45**	5.62	4.09	-1.06
IC-281989 x Him Mash-1	-33.31**	-47.74**	-43.30**	3.44	0.59	40.00**	4.11	0.96	2.14
IC-398973 x HPBU-111	-44.40**	-62.64**	-52.14**	18.75**	2.55	28.24**	7.34	-2.31	9.93*
IC-398973 x Him Mash-1	-58.20**	-70.61**	-68.11**	-11.46**	-15.95**	16.98**	5.31	0.00	12.52**
IC-281982 x HPBU-111	-44.26**	-66.37**	-56.92**	12.70**	10.00	5.06	2.33	1.47	-4.75
IC-281982 x Him Mash-1	13.45	-29.43**	-23.44**	-10.89**	-24.87**	4.57	1.35	-2.31	-1.17
IC-282001 x HPBU-111	-10.48*	-29.52**	-9.71	33.73**	25.79**	29.80**	-1.17	-8.01	-1.47
IC-282001 x Him Mash-1	-38.97**	-48.77**	-44.42**	-4.95	-17.24**	15.18**	6.83	3.87	11.25*
IC-398956 x HPBU-111	-13.59**	-22.99**	-1.34	11.50**	-1.18	16.33**	16.52**	12.89**	11.11*
IC-398956 x Him Mash-1	-3.15	-6.83	1.08	-19.67**	-25.87**	3.18	-8.19*	-9.44*	-8.38
IC-413306 x HPBU-111	16.30**	8.85	39.44**	1.99	-8.43	4.65	16.09**	11.04*	12.25*
IC-413306 x Him Mash-1	16.35**	14.69**	28.08**	7.89*	-1.76	36.73**	6.76	6.72	7.97
IC-413307 x HPBU-111	-23.35**	-38.92**	-21.75**	43.73**	35.21**	39.51**	3.56	0.78	-1.72
IC-413307 x Him Mash-1	-44.29**	-52.62**	-48.60**	-12.70**	-23.99**	5.80	-6.66	-8.34	-7.27
IC-281993 x HPBU-111	-33.44**	-55.38**	-42.84**	4.67	-4.52	5.31	1.58	-5.48	1.32
IC-281993 x Him Mash-1	-18.63**	-42.94**	-38.10**	-0.59	-10.91**	24.00**	-4.06	-6.75	-0.05
IC-343962 x HPBU-111	-32.31**	-55.23**	-42.65**	-1.41	-10.82*	0.24	-5.15	-13.23**	-3.46
IC-343962 x Him Mash-1	-1.44	-31.95**	-26.17**	-5.45	-14.55**	18.94**	-6.97	-11.19**	-1.18
IC-413305 x HPBU-111	27.34**	-6.77	19.43**	6.56	1.97	1.47	16.28**	14.88**	8.64
IC-413305 x Him Mash-1	9.11	-15.53**	-8.36	16.48**	-0.12	39.02**	-4.07	-7.20	-6.12
IC-398998 x HPBU-111	-22.46**	-48.07**	-33.48**	14.94**	3.76	17.14**	9.67*	0.27	11.67*
IC-398998 x Him Mash-1	-18.48**	-42.90**	-38.05**	10.95**	0.47	39.84**	-12.10**	-16.12**	-6.59
IC-281992 x HPBU-111	-22.46**	-48.67**	-34.25**	5.64	-11.92**	20.00**	-0.59	-3.09	-5.83
Traits→	Harvest index (%)			100 seed weight (g)			Protein content (%)		
Crosses ↓	H1	H2	H3	H1	H2	H3	H1	H2	H3
IC-281992 x Him Mash-1	-8.49	-36.75**	-31.38**	-21.16**	-21.99**	8.57	-4.31	-6.20	-5.10
IC-413304 x HPBU-111	-21.46**	-50.14**	-36.12**	54.11**	51.83**	42.29**	6.33	1.05	3.54
IC-413304 x Him Mash-1	-15.07*	-44.01**	-39.26**	-13.77**	-27.86**	0.41	-8.68*	-9.26*	-7.03
IC-436852 x HPBU-111	-32.59**	-57.51**	-45.56**	17.53**	-0.06	29.71**	-4.69	-8.12	-8.62
IC-436852 x Him Mash-1	-25.33**	-51.17**	-47.03**	3.55	0.06	39.27**	3.20	2.33	3.52
IC-282002 x HPBU-111	-13.18*	-40.59**	-23.89**	48.07**	38.78**	44.33**	12.78**	6.88	10.17*

IC-282002 x Him Mash-1	-15.94*	-39.67**	-34.55**	-2.58	-14.90**	18.45**	-5.63	-6.51	-3.63
IC-281990 x HPBU-111	-13.29*	-32.58**	-13.63*	3.24	-6.80	5.22	19.40**	18.33**	11.20*
IC-281990 x Him Mash-1	-19.77**	-33.60**	-27.96**	-9.84**	-18.36**	13.63**	-3.61	-7.04	-5.95
IC-281995 x HPBU-111	-19.62**	-44.85**	-29.34**	27.40**	19.14**	24.49**	5.79	3.32	0.02
IC-281995 x Him Mash-1	-0.17	-28.14**	-22.04**	14.37**	0.12	39.35**	12.77**	10.34*	11.63*
IC-343885 x HPBU-111	-6.52	-31.69**	-12.49**	35.49**	27.17**	31.84**	18.41**	14.42**	13.24**
IC-343885 x Him Mash-1	-3.21	-25.23**	-18.88**	5.82	-7.68*	28.49**	8.00	6.83	8.08
IC-343947 x HPBU-111	-27.55**	-52.50**	-39.15**	6.49	-2.88	7.18	1.18	1.05	-6.50
IC-343947 x Him Mash-1	-0.33	-31.85**	-26.07**	16.52**	4.46	45.39**	-1.59	-5.79	-4.69
IC-282004 x HPBU-111	-39.40**	-54.82**	-42.12**	8.11	1.17	5.55	-0.76	-1.85	-7.38
IC-282004 x Him Mash-1	-30.73**	-45.28**	-40.64**	-10.83**	-21.99**	8.57	-6.09	-9.24	-8.18
IC-413309 x HPBU-111	-8.81	-46.59**	-31.58**	48.05**	39.21**	43.76**	-3.58	-7.04	-7.57
IC-413309 x Him Mash-1	1.28	-39.11**	-33.94**	-14.07**	-25.16**	4.16	-4.90	-5.72	-4.61
IC-343943 x HPBU-111	15.49*	-20.43**	1.93	12.86**	9.87	-0.08	21.49**	20.89**	11.57*
IC-343943 x Him Mash-1	-5.73	-31.83**	-26.05**	0.51	-18.65**	13.22**	15.54**	9.95*	11.23*
IC-281984 x HPBU-111	-7.47	-30.10**	-10.46	25.68**	8.47*	35.84**	1.59	1.53	-6.30
IC-281984 x Him Mash-1	-5.20	-24.01**	-17.56**	-24.11**	-27.92**	0.33	-4.47	-8.72	-7.65
SE±	0.86	1.00	1.00	0.18	0.20	0.20	0.90	1.04	1.04

*, ** Significant at $P \leq 0.05$ & $P \leq 0.01$; respectively H1- heterosis over mid-parent, H2= heterosis over better-parent, H3- Heterosis over standard check i.e. Palampur-93

Conclusion

Crosses IC-343885 x HPBU-111, IC-436910 x HPBU-111, IC-413306 x Him Mash-1 and IC-343943 x HPBU-111 were potential crosses on the basis of mid parent, better parent, standard heterosis and showed desired results for seed yield and most of the traits. Hence, suggested that this hybrid could be further considered in the breeding program aiming both for segregant breeding and hybrid development.

References

1. Chakraborty S, Kumar HB, Kumar BB, Pathak D, Kalita H, Barman B. Genetic parameters and combining ability effects of parents for seed yield and other quantitative traits in blackgram [*Vigna mungo* (L.) Hepper]. Notulae Scientia Biologicae. 2010; 2:121-126.
2. Cheralu C, Satyanarayana A, Kulkarni N. Heterosis for pre harvest sprouting, yield and yield components in mungbean. Ind. J Pul. Res. 2002; 15:128-130.
3. Dabholkar AR. Elements of Biometrical Genetics Concept Publishing Company, New Delhi, 1992, 187-214.
4. Elangaimannan R, Anbuselvam Y, Venkatesan M, Karthikeyan P. Heterosis and inbreeding depression for yield and yield attributes in urdbean. Mad. Agric. J. 2006; 95:453-457.
5. Gill RK, Singh I, Singh S, Singh P. Studies on combining ability for grain yield and component traits in Kharif urdbean. Leg. Res. 2014; 37:575-579.
6. Gopi KA, Reddisekhar M, Raja KA, Subrarnanyarn RK. Heterosis and combining ability studies in urdbean (*Vigna mungo* (L.) hepper). Leg. Res. 2003; 26:280-283.
7. Jackson MK. Soil chemical analysis. Prentice Hall of India Pvt. Ltd., India, 1976.
8. Kant R, Srivastava RK. Heterosis and inbreeding depression studies in urdbean [*Vigna mungo* (L.) Hepper]. J Food Leg. 2012; 25:102-108.
9. Karande SP, Rewale a, Pand Nilakh SB. Combining ability analysis in blackgram. (*Vigna mungo* (L.) hepper). Bioinfolet. 2013; 10:685-688.
10. Lamkey KR, Edwards JW. Quantitative genetics of heterosis. In: (eds. Coors J. G., Pandey S.), The Genetics and Exploitation of Heterosis in Crops. American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America, Madison, 1999.
11. Manivannan N. Genetic diversity in cross derivatives of greengram (*Vigna radiata* L. Wilczek). Leg. Res. 2002; 25:50-52.
12. Mole RH, Solhuana WS, Robinson HF. Heterosis and genetic diversity in variety crosses of maize. Crop Sci. 1962; 2:197-198.
13. Natarajan C, Rathanasamy R. Heterosis and inbreeding depression in blackgram. Mad. Agric. J. 2000; 86:447-450.
14. Neog SB, Talukar P. Journal of the Agricultural Science Society of North-East India. 1999; 12:210-216.
15. Nijhawan DC. Studies on the physiological basis of yield differences in some varieties of mungbean (*Phaseolus aureus* Roxb.) and the nature of gene action governing these characters. PhD thesis Haryana Agric Univ, Hissar, India, 1975.
16. Sethi SC. Gene action governing some quantitative characters in mungbean. PhD thesis Haryana Agric Univ, Hissar, India, 1975.
17. Shull GH. A pure line method of corn breeding. Amer. Breed. Assoc. Ann. Report. 1908; 5:51-59.
18. Singh DP. Genetics and breeding of black gram and green gram. Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttar Pradesh (now Uttaranchal) Research Bulletin, 2000, 109:68.
19. Sonawane, Rajendra V. Heterosis and combining ability studies in mungbean (*Vigna* rad5iata L. Wilczek). M.Sc. Thesis. Vasantrao Naik Marathwada Krishi Vidyapeeth, Agricultural university, Parbhani, 2015.
20. Sujatha K, Kajjidoni ST, Patil PV and Somashekhar G. 2011. Heterosis for productivity related traits involving diverse parents for powdery mildew reaction in mungbean. J Food Leg. 24: 101-105.
21. Thamodharan G, Ramalingam A, Geetha S. Estimation of genetic parameters and combining ability analysis in blackgram [*Vigna mungo* (L.) Hepper]. Leg. Res. 2017; 4:401-408.
22. Thangavel P. Studies on heterosis in black gram [*Vigna mungo* (L.) Hepper]. Int. J Rec. Sci. Res. 2010; 1:204-205.
23. Vaithiyalingam M. Heterosis for yield yield components in blackgram (*Vigna mungo*). J Ecobio. 2004; 16:87-91.
24. Vikas, Singh SP. Heterosis for yield and its contributing characters over environment in mungbean [*Vigna radiata* (L.) Wilczekj. Ann. Bioinfor. 1998; 14:175-179.
25. Zubair M, Ajmal SU, Ali S. Heterosis for yield related attributes in Mungbean [*Vigna Radiata* (L.) Wilczek]. Pak. J Bot. 2010; 42:3209-3214.