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Heterosis for seed yield and yield contributing characters of Kabuli x Kabuli crosses of chickpea (*Cicer arietinum* L.)

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Abstract
The experiment was conducted at Pulses Research Unit, Dr. P.D.K.V. Akola, during *Rabi* season of 2017-18. In this study, four lines were crossed with six male parents by using line x tester design and twenty four hybrids were developed. These twenty four hybrids along with their parental lines and checks (3) *viz.*, Virat, PKV Kabuli-4 and PKV Kabuli-2, were grown during *Rabi* season of 2017-18. The cross PKV Kabuli-2 x Shubhra was recorded highest mean performance for seed yield (24.35 g) and significant standard heterosis (70.28%, 60.20% and 45.37% over check PKV Kabuli-4, Virat and PKV Kabuli-2 respectively), heterobeltiosis (48.48%) and average heterosis (63.70%). Another cross PKV Kabuli-2 x BDNGK-798 revealed high mean performance for (20.55 g) for seed yield per plant also recoded high magnitude of useful heterosis (43.71%, 35.20% and 22.69% over check PKV Kabuli-4, Virat and PKV Kabuli-2 respectively).

Keywords: heterosis, heterobeltiosis, standard heterosis and line x tester design chickpea

Introduction
Chickpea (*Cicer arietinum* L.) is the third most important food legume (after dry bean and pea) globally, grown in over 40 countries representing all the continents. Over 90% of area, production and consumption are in developing countries. Presently, the most important chickpea producing countries are India, Australia, Pakistan, Turkey, Myanmar, Ethiopia, Iran USA, Canada and Mexico. India is the largest chickpea producer as well as consumer in the world sharing 69.75 and 70.71 per cent of the total area and production, respectively. In India chickpea cultivation was done on 9.60 million ha with production of 8.83 million tons in the year 2013. In spite of India being the largest chickpea producing country a deficit exists in domestic production.

About 85% of the total chickpea production in the world is of *desi* type. *Kabuli* type though much in demand is not much grown here because of its poor yield and relatively higher water requirement. Recently there is increase in area under *kabuli* chickpeas in Andhra Pradesh as farmers are getting attracted towards *kabuli* especially extra large seeded *kabuli* on account of its premium price in the markets and demand, which is met through imports. Chickpea has special significance in the diet of the predominantly vegetarian population of India as it contains more protein (23%), which is complementary with cereals in amino acids profile. However, production and productivity of chickpea have been stagnant for the past three decades. Therefore there is need to incorporate drought tolerance into *kabuli* chickpeas for attaining stable yields under receding soil moisture conditions. Therefore, keeping this in mind the present investigation was carried out to estimate degree of heterosis. The exploitation of heterosis is one of the breeding strategies to enhance the productivity. Line x Tester analysis is an extension of top cross method in which several testers are used which provides information about general and specific combining ability of parents and at the same time it is helpful in identifying best heterotic crosses.

Materials and Methods
Present research was conducted at Pulses Research Unit, Dr. PDKV, Akola. The parent material for the study consisted of four lines *viz.*, PKV Kabuli-2, BDNGK-807, Chanoli, Kripa, and six testers *viz.*, Virat, BDNGK-798, Phule G-12310, Shubhra, Phule G-0739,

MNK-1. Crossing work was done in *rabi* 2016-17 and evaluation was done in *rabi* 2017-18, resultant 24 crosses ten parents and three checks (Virat, PKV Kabuli-4 and PKV Kabuli-2) were sown in RBD design with two replications for evaluation. Each entry was sown in one row of 4 m length in each replication with inter and intra-row spacing was 45 cm and 10 cm, respectively. All the standard agronomic and plant protection measures were used. The data was recorded on plant basis and plot basis, from each genotype in each replication on 5 randomly selected plants and their average value was computed for ten quantitative traits *viz.*, days to 50% flowering, days to maturity, plant height (cm), number of primary branches, number of secondary branches, number of pods per plant, number of seeds per pod, 100 seed weight (g) empty pods per plant, seed yield per plant (g). Heterosis was calculated over mid parent, better parent and standard checks. For seed yield and other yield contributing traits. Data in each experiment of all entries was subjected to analysis of variance (Panse and Sukhatme, 1967) for testing the significance of treatments. Heterosis was calculated by standard procedure.

Result and Discussion

The mean sum of square form analysis of variences of ten chickpea traits are presented in (Table 1). It is evident for the table that highly significant differences among chickpea genotypes, parent, parent vs crosses. Highly significant crosses among parent vs crosses indicated the presence of considerable heterosis for all the studied traits. The significance differances could be attributed to genetically divers nature of female and male parents. The estimates of heterosis, heterobeltiosis and standard heterosis for indicated chickpea traits are presented in (Table 2).

Days taken to 50% flowering are of significance in the sence that if flowering start earlier, sufficient time will be available for grain formation process. Thus early flowering is desirable in chickpea and negative heterosis for days to 50% flower inition is useful. Out of 24 crosses, 1 and 3 crosses showed significant and negative average heterosis and heterobeltiosis respectively. Highest significant negative average heterosis and heterobeltiosis was observed in the cross Chanoli x Phule G-12310 (-10.60% and -17.09%). The cross PKV Kabuli-2 x Phule G-12310 (-9.62%) recorded significant negative standard heterosis over check PKV Kabuli-2. Means these crosses are early flowering. These results are in close conformite with the finding of Singh and Paroda (1989) [7], who also reported negative heterosis for days to 50% flowering.

Days taken to maturity are an effective trait for earliness and thus negative heterosis for this trait is desirable. Out of 24 crosses 8, 19 and 4 crosses showed significant, negative and highest average heterosis, heterobeltiosis and standard heterosis respectively. Maximum significant and negative average heterosis was observed in cross PKV Kabuli-2 x Phule G-12310 (-8.01%). Highest significant and negative heterobeltiosis was observed in cross Chanoli x Phule G 12310 (-13.15%). Also significant and negative standard heterosis was recorded in Cross PKV Kabuli-2 x Phule G-12310 (-7.29) over check Virat. These results are in close conformite with the finding of Singh and Paroda (1989) [7], Sarode (1997) who also reported negative heterosis for days to maturity.

Heterotic studied for number of pods per plant posisitive heterosis is also most important releted to increase the yield. Out of 24 crosses, 8, 4 crosses showed significant and positive average heterosis over mid parent and better parent respectively. The cross PKV Kabuli-2 x Shubhra depicted the highest significant positive average heterosis (60.89%) and heterobeltiosis (53.41%). The same cross depicted the highest significant and positive standard heterosis over 3 checks, 21.42% over check Virat, 47. 18% over check PKV Kabuli-2. For this character good amount of heterosis was reported by Tiwari and Pandey (1987) [8], Singh and Paroda (1989) [7]

For 100 seed weight, Out of 24 crosses, 10, 3 crosses showed significant and positive heterosis over mid parent and heterobeltiosis respectively. The cross BDNGK-807 x Virat exhibited highest significant and positive average heterosis (21.08%) and heterobeltiosis (11.19%). The cross Kripa x MNK-1 (28.0%) exhibited significant and positive standard heterosis followed by PKV Kabuli x MNK-1 (23.07%). Similar result was previously recorded by Gupta *et al.* (2003) [3] and Tiwari and Pandey (1985).

The traits number of seeds per pod, out of 24 crosses only one cross Chanoli x MNK-1 (11.11%) exhibited significant and positive heterosis. The cross Chanoli x BDNGK-798 (29.63) exhibited highest standard heterosis over check Virat followed by Chanoli x MNK-1 (15.74%). For this character good amount of heterosis was reported by Tiwari and Pandey (1987) [8], Singh and Paroda (1989) [7].

Seed yield is the complex character decides the economic worth of the crosses. Out of 24 crosses, 5, 4 crosses exhibited significant positive heterosis over mid parent and better parent respectively. The cross PKV Kabuli-2 x Shubhra exhibited highest significant and positive average heterosis (63.70%) and heterosbeltiosis (48.48%). The cross PKV Kabuli-2 x Shubhra also exhibited significant and positive standard heterosis over 3 checks (70.28%, 60.20%, 45.37%, over check Virat, PKV Kabuli-4, PKV Kabuli-2 respectively) followed by PKV Kabuli-2 x BDNGK-798 (35.20%, 43.71%, 22.69% over check Virat, PKV Kabuli-4, PKV Kabuli-2 respectively). The significant positive heterosis for seed yield per plant has also been reported by Singh and Paroda (1989) [7], Kulkarni *et al.* (2004) [4] and Gadekar and Dodiya (2013) [2].

Conclusion

In this study, line x tester analysis on the basis of mean seed yield performance, average heterosis, heterobeltiosis, standard heterosis, the crosses PKV Kabuli-2 x Shubhra and PKV Kabuli-2 x BDNGK-798 were found to be the most promising crosses among all the 24 crosses studied. And the cross PKV Kabuli-2 x Phule G-12310 recorded early for 50% flowering and maturity.

Table 1: Analyasis Of Variance for Various Traits

Sources	d. f.	Days to 50% lowering	Days to maturity	Plant height (cm)	Number of primary branches	Number of secondary branches	Number of pods per plant	100 seeds weight (g)	Number of seed per pod	Number of empty pods per plant	Seed yield per plant (g)
		1	2	3	4	5	6	7	8	9	10
Replications	1	0.059	15.020	0.100	0.660	0.0001	32.762	0.031	0.000	0.002	3.597
Treatments	33	38.47**	41.11**	31.69**	0.812**	27.00**	211.32**	285.69**	0.033**	1.016**	30.758**
Parents	9	22.42**	48.89**	8.138	0.764*	39.60**	194.91**	331.41**	0.058**	0.190	16.523**
Parents vs Crosses	1	59.81**	148.73**	56.66*	0.760	6.134	221.433**	67.251**	0.1046**	0.720**	0.759
Crosses	23	43.82**	33.39**	39.83**	0.83**	22.97**	217.303**	277.301**	0.0208**	1.352**	37.63**
Error	33	4.96	3.66	11.64	0.27	2.15	13.747	0.805	0.003	0.095	1.563

Note: * Significant at 5% level of significance, ** Significant at 1% level of significance

Table 2: Estimation of heterosis (%) over mid-parent (H_1), better parent (H_2) and standard checks (H_{3a}, H_{3b}, H_{3c}) for yield and other yield contributing traits

Sr. No	Crosses	Days to 50% Flowering					Days to Maturity				
		MP(H_1)	BP(H_2)	(H_{3a})	(H_{3b})	(H_{3c})	MP(H_1)	BP(H_2)	(H_{3a})	(H_{3b})	(H_{3c})
1	PKV Kabuli-2 x Virat	7.98 *	3.6	7.48	13.86 **	10.5*	-5.29 **	-5.53 **	-2.08	-5.05 *	-4.08 *
2	PKV Kabuli-2 x BDNGK-798	7.84 *	7.84	2.8	8.91	5.77	-1.96	-4.31 *	4.17 *	1.01	2.04
3	PKV Kabuli-2 x Phule G-12310	-6.93	-7.84	-12.15**	-6.93	-9.62*	-8.01 **	-10.55**	-7.29**	-10.10 **	-9.18 **
4	PKV Kabuli-2 x Shubhra	0	-0.98	-5.61	0	-2.88	-5.29 **	-5.53 **	-2.08	-5.05 *	-4.08 *
5	PKV Kabuli-2 x Phule G-0739	2.54	-0.98	-5.61	0	-2.88	-3.43	-8.04 **	-4.69 *	-7.58 **	-6.63 **
6	PKV Kabuli-2 x MNK-1	-5.66	-9.09 *	-6.54	-0.99	-3.85	-5.76 **	-6.00 **	-2.08	-5.05 *	-4.08 *
7	BDNGK-807 x Virat	-4.76	-9.91 *	-6.54	-0.99	-3.85	-2.84	-5.05 *	-2.08	-5.05 *	-4.08 *
8	BDNGK-807 x BDNGK-798	11.44 **	9.80 *	4.67	10.89 *	7.69	-1.01	-5.74 **	2.6	-0.51	0.51
9	BDNGK-807 x PhuleG-12310	-1.51	-2	-8.41	-2.97	-5.77	-3.45	-3.7	-5.21 *	-8.08 **	-7.14 **
10	BDNGK-807 x Shubhra	1.51	1	-5.61	0	-2.88	-2.84	-5.05 *	-2.08	-5.05 *	-4.08 *
11	BDNGK-807 x Phule G-0739	1.03	-1.01	-8.41	-2.97	-5.77	-2.44	-4.76 *	-6.25**	-9.09 **	-8.16 **
12	BDNGK-807 x MNK-1	-2.39	-7.27	-4.67	0.99	-1.92	-3.34	-6.00 **	-2.08	-5.05 *	-4.08 *
13	Chanoli x Virat	-3.51	-5.98	2.8	8.91	5.77	-5.60 **	-8.92 **	1.04	-2.02	-1.02
14	Chanoli x BDNGK-798	17.81 **	10.26 *	20.5**	27.72 **	24.04 **	-0.47	-1.41	9.38 **	6.06 **	7.14 **
15	Chanoli x Phule G-12310	-10.60**	-17.09**	-9.35 *	-3.96	-6.73	-7.73 **	-13.15**	-3.65	-6.57 **	-5.61 **
16	Chanoli x Shubhra	13.36 **	5.13	14.9**	21.78 **	18.2**	-6.57 **	-9.86 **	0	-3.03	-2.04
17	Chanoli x Phule G-0739	12.26 **	1.71	11.21*	17.82 **	14.4**	-3.31	-10.80**	-1.04	-4.04 *	-3.06
18	Chanoli x MNK-1	3.96	0.85	10.28*	16.83 **	13.4**	-2.18	-5.16 **	5.21 *	2.02	3.06
19	Kripa x Virat	9.86 *	5.41	9.35 *	15.84 **	12.5**	-2.24	-6.22 **	-3.44	-1.01	-6.63 **
20	Kripa x BDNGK-798	12.75 **	12.75**	7.48	13.86 **	10.5*	-1.46	-2.87	5.73 **	2.53	3.57
21	Kripa x Phule G-12310	12.87 **	11.76 *	6.54	12.87 **	9.62 *	0.26	-3.45	2.08	-1.01	0
22	Kripa x Shubhra	8.91 *	7.84	2.8	8.91	5.77	-4.74 **	-5.91 **	-0.52	-3.54	-2.55
23	Kripa x Phule G-0739	6.6	2.94	-1.87	3.96	0.96	-0.26	-5.91 **	-0.52	-3.54	-2.55
24	Kripa x MNK-1	-4.72	-8.18	-5.61	0	-2.88	1.24	0.49	6.25 **	3.03	4.08 *
	RANGE	-10.60 to 12.87	-17.09 to 12.75	-12.15 to 20.5	-6.93 to 27.72	-9.62 to 24.04	-8.01 to 1.24	-13.15 to 0.49	-7.29 to 9.38	-10.10 to 6.06	-9.18 to 7.14
	SE(D)±	1.93	2.23	2.23	2.23	2.23	1.66	1.91	1.91	1.91	1.91
	CD 5%	3.99	4.61	4.61	4.61	4.61	3.43	3.96	3.96	3.96	3.96
	CD 1%	5.41	6.26	6.26	6.26	6.26	4.65	5.37	5.37	5.37	5.37

Note: * Significant at 5% level of significance, ** Significant at 1% level of significance

Where, H_{3a} - Standard heterosis over check Virat

H_{3b} - Standard heterosis over check PKV kabuli-4

H_{3c} - Standard heterosis over check PKV kabuli-2

Sr. No	Crosses	Plant Height (cm)					No. of primary branches				
		MP(H_1)	BP(H_2)	(H_{3a})	(H_{3b})	(H_{3c})	MP(H_1)	BP(H_2)	(H_{3a})	(H_{3b})	(H_{3c})
1	PKV Kabuli-2 x Virat	-6.55	-8.61	-4.28	-5.91	-10	6.8	-3.51	-5.17	30.95 *	4.76
2	PKV Kabuli-2 x BDNGK-798	13.07	10.85	10.98	9.09	4.35	10.2	3.85	-6.9	28.57*	2.86
3	PKV Kabuli-2 x Phule G-12310	6.81	5.08	5.2	3.41	-1.09	-1.05	-4.08	-18.97 *	11.9	-10.48
4	PKV Kabuli-2 x Shubhra	10.99	8.08	13.29	11.36	6.52	13.83	11.46	-7.76**	27.38	1.9
5	PKV Kabuli-2 x Phule G-0739	-10.3	-11.55	-11.45	-12.95	-16.74 *	-2	-9.26	-15.52	16.67	-6.67
6	PKV Kabuli-2 x MNK-1	-7.08	-10.62	-10.52	-12.05	-15.87 *	-12.09	-13.04	-31.03 **	-4.76	-23.81 *
7	BDNGK-807 x Virat	-2.14	-8.61	-4.28	-5.91	-10	-10.89	-21.05 *	-22.41 *	7.14	-14.29
8	BDNGK-807 x BDNGK-798	4.31	1.44	-2.43	-4.09	-8.26	27.08 **	17.31	5.17	45.24 **	16.19
9	BDNGK-807 x Phule G-12310	-6.17	-9.07	-11.91	-13.41	-17.17 *	-20.43 *	-24.49 *	-36.21 **	-11.9	-29.52 **
10	BDNGK-807 x Shubhra	18.61*	11.11	15.61	13.64	8.7	-8.7	-12.5	-27.59 **	0	-20
11	BDNGK-807 x Phule G-0739	-9.1	-12.11	-14.45	-15.91	-19.57 *	2.04	-7.41	-13.79	19.05	-4.76
12	BDNGK-807 x MNK-1	-3.42	-4.25	-11.45	-12.95	-16.74 *	-5.62	-6.67	-27.59 **	0	-20
13	Chanoli x Virat	-18.65*	-22.96**	-19.31 *	-20.68 *	-24.13**	-32.50 **	-35.71 **	-36.21 **	-3.57	-22.86 *
14	Chanoli x BDNGK-798	-14.01	-15.14	-18.38 *	-19.77 *	-23.26 **	2.61	-6.35	1.72	40.48**	12.38
15	Chanoli x Phule G-12310	-6.31	-7.88	-10.75	-12.27	-16.09 *	0	-11.11	-3.45	33.33 *	6.67
16	Chanoli x Shubhra	-6.2	-10.89	-7.28	-8.86	-12.83	-17.12 *	-26.98 **	-20.69 *	9.52	-12.38
17	Chanoli x Phule G-0739	-13.56	15.2	-17.46 *	-18.86 *	-22.39 **	-19.66 *	-25.40 **	-18.97 *	11.9	-10.48
18	Chanoli x MNK-1	-19.50*	-20.00*	-25.09 **	-26.36 **	-29.57 **	-14.81	-26.98 **	-20.69 *	9.52	-12.38
19	Kripa x Virat	-10.48	-12.36	-8.21	-9.77	-13.7	3.92	-7.02	-8.62	26.19 *	0.95
20	Kripa x BDNGK-798	-2.82	-4.84	-4.51	-6.14	-10.22	-11.34	-17.31	-25.86 **	2.38	-18.1
21	Kripa x Phule G-12310	-1.52	-3.23	-2.89	-4.55	-8.7	-5.32	-9.18	-23.28 *	5.95	-15.24
22	Kripa x Shubhra	-2.94	-4.67	-0.81	-2.5	-6.74	16.13	12.5	-6.9	28.57 *	2.86
23	Kripa x Phule G-739	-10.18	-11.52	-11.21	-12.73	-16.52 *	-17.17	-24.07 *	-29.31 **	-2.38	-21.90 *
24	Kripa x MNK-1	-12.47	-15.9	-15.61	-17.05 *	-20.65 *	2.22	2.22	-20.69 *	9.52	-12.38
	RANGE	-19.50 to 18.61	-22.96 to 11.11	-25.09 to 15.61	-26.36 to 13.64	-29.57 to 8.7	-32.50 to 27.08	-35.71 to 12.5	-36.21 to 5.17	-11.9 to 45.24	-29.52 to 16.19
	SE(D)±	2.96	3.41	3.41	3.41	3.41	0.45	0.52	0.52	0.52	0.52
	CD 5%	6.11	7.06	7.06	7.06	7.06	0.94	1.08	1.08	1.08	1.08
	CD 1%	8.30	9.58	9.58	9.58	9.58	1.27	1.47	1.47	1.47	1.47

Note: * Significant at 5% level of significance, ** Significant at 1% level of significance
Where, H_{3a} - Standard heterosis over check Virat
H_{3b} - Standard heterosis over check PKV kabuli-4
H_{3c} - Standard heterosis over check PKV kabuli-2

Sr. No	Crosses	No. of secondary branches					No. of Pods per plant				
		MP(H_1)	BP(H_2)	(H_{3a})	(H_{3b})	(H_{3c})	MP(H_1)	BP(H_2)	(H_{3a})	(H_{3b})	(H_{3c})
1	PKV Kabuli-2 x Virat	-2.41	-20.9**	-10.28	13.61	14.97	-4.24	-8.92	-20.11 **	55.43**	-3.16
2	PKV Kabuli-2 x BDNGK-798	25.90**	11.54	1.64	28.70 **	30.24 **	31.4**	28.24 **	1.49	97.46**	23.02*
3	PKV Kabuli-2 x Phule G-12310	1.05	-8.15	-21.03 **	0	1.2	21.26 *	0	-20.86 **	53.99**	-4.06
4	PKV Kabuli-2 x Shubhra	50.08**	49.34**	6.07	34.32 **	35.93 **	60.89 **	53.41 **	21.42 **	136.23**	47.18 **
5	PKV Kabuli-2 x Phule G-0739	1.05	-8.15	-21.03 **	0	1.2	0.58	0	-19.93 **	55.80**	-2.93

6	PKV Kabuli-2 x MNK-1	-3.34	18.27	-42.52 **	-27.22 **	-26.35 **	-22.40 *	-37.65 **	-50.65 **	-3.99	-40.18 **
7	BDNGK-807 x Virat	-11.17	-26.34**	-16.36 *	5.92	7.19	11.81	-5.52	-17.13 *	61.23**	0.45
8	BDNGK-807 x BDNGK-798	4.23	-5.13	-13.55	9.47	10.78	10.56	-0.25	-24.95 **	46.01**	-9.03
9	BDNGK-807 x Phule G-12310	-12.21	-17.93*	-29.44 **	-10.65	-9.58	36.44 **	26.15 *	-23.65 **	48.55**	-7.45
10	BDNGK-807 x Shubhra	3.21	0.63	-24.77 **	-4.73	-3.59	38.78 **	27.89**	-8.19	78.62**	11.29
11	BDNGK-807 x Phule G-0739	-7.56	-13.59	-25.70 **	-5.92	-4.79	-0.66	-12.79	-30.17 **	35.87*	-15.35
12	BDNGK-807 x MNK-1	32.95**	9.69	-17.99 *	3.85	5.09	21.78	9.23	-33.89 **	28.62*	-19.86 *
13	Chanoli x Virat	-18.38**	-19.84**	-5.61	19.53 *	20.96 *	-3.06	-12.93	-4.1	86.59**	16.25
14	Chanoli x BDNGK-798	-4.7	-15.48 *	-0.47	26.04 **	27.54 **	16.52 *	-1.94	8.01	110.14**	30.93 **
15	Chanoli x Phule G-12310	17.43**	1.59	19.63 **	51.48 **	53.29 **	20.69 *	-6.09	3.45	101.27**	25.40 **
16	Chanoli x Shubhra	23.27**	-1.19	16.36 *	47.34 **	49.10 **	13.72 *	-11.5	-2.51	89.67**	18.17 *
17	Chanoli x Phule G-0739	0.46	-13.10 *	2.34	29.59 **	31.14 **	-12.09	-24.09 **	-16.39 *	62.68**	1.35
18	Chanoli x MNK-1	-3.93	-32.14**	-20.09 **	1.18	2.4	-3.35	-30.60 **	-23.56 **	48.73**	-7.34
19	Kripa x Virat	5.53	-13.58 *	-1.87	24.26 *	25.75 **	16.41	-0.21	-12.48	70.29**	6.09
20	Kripa x BDNGK-798	-5.14	-14.87	-22.43 **	-1.78	-0.6	-13.84	-21.04 *	-40.60 **	15.58*	-27.99 **
21	Kripa x Phule G-12310	-5.01	-12.5	-24.77 **	-4.73	-3.59	1.88	-7.28	-41.90 **	13.04*	-29.57 **
22	Kripa x Shubhra	14.01	12.9	-18.22 *	3.55	4.79	17.17	9.73	-21.23 **	53.26**	-4.51
23	Kripa x Phule G-0739	-24.48**	-30.43**	-40.19 **	-24.26 *	-23.35 *	-12.59	-22.09 *	-37.62 **	21.38**	-24.38 **
24	Kripa x MNK-1	32.05 **	10.32	-20.09 **	1.18	2.4	-33.73 **	-41.46 **	-63.31 **	-28.62	-55.53 **
	RANGE	-24.48 to 50.08	-32.14 to 49.34	-42.52 to 19.63	-27.22 to 51.58	-26.35 to 53.29	-33.73 to 60.89	-41.46 to 53.41	-63.31 to 21.42	-28.62 to 110	-55.53 to 47.18
	SE(D)±	1.27	1.47	1.47	1.47	1.47	3.21	3.71	3.71	3.71	3.71
	CD 5%	2.63	3.04	3.04	3.04	3.04	6.64	7.67	7.67	7.67	7.67
	CD 1%	3.57	4.12	4.12	4.12	4.12	9.01	10.41	10.41	10.41	10.41

Note: * Significant at 5% level of significance, ** Significant at 1% level of significance

Where, H_{3a} - Standard heterosis over check Virat

H_{3b} - Standard heterosis over check PKV kabuli-4

H_{3c} - Standard heterosis over check PKV kabuli-2

Sr. No	Crosses	100 seed weight (g)					No. of seeds per pod				
		MP(H_1)	**BP(H_2)**	**(H_{3a})**	**(H_{3b})**	**(H_{3c})**	**MP(H_1)**	**BP(H_2)**	**(H_{3a})**	**(H_{3b})**	**(H_{3c})**
1	PKV Kabuli-2 x Virat	15.19**	-1.27	33.62**	-26.19**	3.33	-4.31	-8.26	-7.41	0	0
2	PKV Kabuli-2 x BDNGK-798	7.79 **	-5.73 *	27.59**	-29.52**	-1.33	-12.82 *	-23.88**	-5.56	2	2
3	PKV Kabuli-2 x Phule G-12310	5.99 **	5.00 *	44.83**	-20.00**	12.0**	-13.19**	-24.44**	-5.56	2	2
4	PKV Kabuli-2 x Shubhra	14.29 **	-3.18	31.03**	-27.62**	1.33	-4.76	-9.09	-7.41	0	0
5	PKV Kabuli-2 x Phule G-0739	-0.44	-0.76	35.17**	-25.33**	4.53	0	0	-7.41	0	0
6	PKV Kabuli-2 x MNK-1	-4.85 **	-20.09**	59.14**	-12.10**	23.07**	0	0	-7.41	0	0
7	BDNGK-807 x Virat	21.08 **	11.19 **	28.45**	-29.05**	-0.67	2.87	-1.38	-0.46	7.5	7.5
8	BDNGK-807 x BDNGK-798	12.88 **	5.97 *	22.41**	-32.38**	-5.33 *	-10.26 *	-21.64**	-2.78	5	5
9	BDNGK-807 x Phule G-12310	8.84 **	0	37.93**	-23.81**	6.67 *	-14.89**	-25.93**	-7.41	0	0
10	BDNGK-807 x Shubhra	7.00 *	-2.99	12.07**	-38.10**	-13.33**	0	-4.55	-2.78	5	5
11	BDNGK-807 x Phule G-0739	7.95 **	-0.25	35.86**	-24.95**	5.07 *	0	0	-7.41	0	0
12	BDNGK-807 x MNK-1	-11.23**	-29.87**	39.66**	-22.86**	8.00 **	0	0	-7.41	0	0

13	Chanoli x Virat	-16.95**	-42.92**	-44.83**	-69.52**	-57.33**	-0.85	-7.2	7.41	16.00*	16.00 *
14	Chanoli x BDNGK-798	-14.79**	-42.18**	-41.38**	-67.62**	-54.67**	8.11	4.48	29.63 **	40.00**	40.00**
15	Chanoli x Phule G-12310	-42.57**	-63.75**	-50.00**	-72.38**	-61.33**	-17.31**	-20.37**	-0.46	7.5	7.5
16	Chanoli x Shubhra	-15.23**	-41.28 **	-44.83**	-69.52**	-57.33**	-2.13	-8	6.48	15.00 *	15.00 *
17	Chanoli x Phule G-0739	-68.00**	-79.75 **	-72.41**	-84.76**	-78.67**	-6.67	-16.00**	-2.78	5	5
18	Chanoli x MNK-1	-61.03**	-76.97 **	-54.14**	-74.67**	-64.53**	11.11 *	0	15.74 *	25.00**	25.00**
19	Kripa x Virat	-9.90 **	-28.65 **	18.10 **	-34.76**	-8.67 **	-16.83**	-26.83**	-2.78	5	5
20	Kripa x BDNGK-798	7.88 **	-13.02 **	43.97 **	-20.48**	11.33 **	-25.05**	-27.53**	-3.7	4	4
21	Kripa x Phule G-12310	-5.68 **	-13.54 **	43.10 **	-20.95**	10.67 **	-28.19**	-30.31**	-7.41	0	0
22	Kripa x Shubhra	-0.33	-21.88 **	29.31 **	-28.57**	0	-17.16**	-26.83**	-2.78	5	5
23	Kripa x Phule G-0739	-5.83 **	-14.17 **	42.07 **	-21.52**	9.87 **	-17.86**	-30.31**	-7.41	0	0
24	Kripa x MNK-1	-9.22 **	-16.88**	65.52 **	-8.57 **	28.00 **	2.67	-12.89**	15.74 *	25.00**	25.00**
	RANGE	-68.0 to 21.08	-79.75 to 11.19	-72.41 to 65.52	-84.76 to -8.57	-78.67 to 28.00	-28.19 to 11.11	-30.31 to 4.48	-7.41 to 29.63	0 to 40	0 to 40
	SE(D)±	0.77	0.89	0.89	0.89	0.89	0.05	0.062	0.062	0.062	0.062
	CD 5%	1.60	1.85	1.85	1.85	1.85	0.11	0.12	0.12	0.12	0.12
	CD 1%	2.18	2.52	2.52	2.52	2.52	0.15	0.17	0.17	0.17	0.17

Note: * Significant at 5% level of significance, ** Significant at 1% level of significance

Where, H_{3a} - Standard heterosis over check Virat

H_{3b} - Standard heterosis over check PKV kabuli-4

H_{3c} - Standard heterosis over check PKV kabuli-2

Sr. No	Crosses	No. of empty pods per plant					Seed yield per plant (g)				
		MP(H_1)	**BP(H_2)**	**(H_{3a})**	**(H_{3b})**	**(H_{3c})**	**MP(H_1)**	**BP(H_2)**	**(H_{3a})**	**(H_{3b})**	**(H_{3c})**
1	PKV Kabuli-2 x Virat	-0.67	-9.76	0	-13.95	-20.43 **	3.64	1.65	9.67	16.57	-0.48
2	PKV Kabuli-2 x BDNGK-798	47.45 **	44.29 **	36.49 **	17.44 *	8.6	37.46 **	25.30 **	35.20 **	43.71 **	22.69 **
3	PKV Kabuli-2 x Phule G-12310	13.1	5.13	10.81	-4.65	-11.83	9.6	0.91	8.88	15.73	-1.19
4	PKV Kabuli-2 x Shubhra	22.88 **	9.3	27.03 **	9.3	1.08	63.70 **	48.48 **	60.20 **	70.28 **	45.37 **
5	PKV Kabuli-2 x Phule G-0739	10.34	2.56	8.11	-6.98	-13.98 *	3.85	1.95	10	16.92	-0.18
6	PKV Kabuli-2 x MNK-1	-38.69 **	-40.00 **	-43.24 **	-51.16 **	-54.84 **	-20.16 **	-25.40 **	-19.51 *	-14.44	-26.96 **
7	BDNGK-807 x Virat	12.42	4.88	16.22	0	-7.53	21.76 *	4.69	8.62	15.45	-1.43
8	BDNGK-807 x BDNGK-798	16.31 *	15.49	10.81	-4.65	-11.83	14.12	5.04	-6.71	-0.84	-15.34
9	BDNGK-807 x Phule G-12310	10.07	5.13	10.81	-4.65	-11.83	32.41 **	20.65 *	9.54	16.43	-0.6
10	BDNGK-807 x Shubhra	-31.21 **	-37.21 **	-27.03 **	-37.21 **	-41.94 **	39.27 **	28.84 **	13.16	20.28 *	2.69
11	BDNGK-807 x Phule G-0739	15.44 *	10.26	16.22	0	-7.53	-1.66	-15.51	-12.17	-6.64	-20.30 *
12	BDNGK-807 x MNK-1	-34.75 **	-35.21 **	-37.84 **	-46.51 **	-50.54 **	7.03	-3.86	-9.87	-4.2	-18.21 *
13	Chanoli x Virat	-7.69	-12.2	-2.7	-16.28 *	-22.58 **	-21.57 *	-40.27 **	-38.03 **	-34.13 **	-43.76 **
14	Chanoli x BDNGK-798	-8.33	-10.81	-10.81	-23.26 **	-29.03 **	0.23	-19.26 *	-28.29 **	-23.78 *	-34.93 **
15	Chanoli x Phule G-12310	-44.74 **	-46.15 **	-43.24 **	-51.16 **	-54.84 **	-26.08 *	-40.94 **	-46.38 **	-43.01 **	-51.34 **
16	Chanoli x Shubhra	-37.50 **	-41.86 **	-32.43 **	-41.86 **	-46.24 **	0	-19.1	-28.95 **	-24.48 *	-35.52 **
17	Chanoli x Phule G-0739	-7.89	-10.26	-5.41	-18.60 *	-24.73 **	-64.57 **	-73.04 **	-71.97 **	-70.21 **	-74.57 **
18	Chanoli x MNK-1	-2.78	-5.41	-5.41	-18.60 *	-24.73 **	-35.56 **	-49.12 **	-52.30 **	-49.30 **	-56.72 **
19	Kripa x Virat	2.63	-4.88	5.41	-9.3	-16.13 *	-5.71	-12.96	6.71	13.43	-3.16

20	Kripa x BDNG-798	17.14 *	17.14	10.81	-4.65	-11.83	-15.98 *	-27.56 **	-11.18	-5.59	-19.40 *
21	Kripa x Phule G-12310	-27.03 **	-30.77 **	-27.03 **	-37.21 **	-41.94 **	-20.95 **	-31.20 **	-15.66	-10.35	-23.46 **
22	Kripa x Shubhra	-33.33 **	-39.53 **	-29.73 **	-39.53 **	-44.09 **	-0.89	-14.94 *	4.28	10.84	-5.37
23	Kripa x Phule G-0739	-4.05	-8.97	-4.05	-17.44 *	-23.66 **	-16.94 *	-23.26 **	-5.92	0	-14.63
24	Kripa x MNK-1	-5.71	-5.71	-10.81	-23.26 **	-29.03 **	-33.40 **	-41.24 **	-27.96 **	-23.43 *	-34.63 **
	RANGE	-44.74 to 47.45	-46.15 to 44.29	-43.24 to 36.46	-51.16 to 17.44	-54.84 to 8.6	-64.57 to 63.70	-73.04 to 48.48	-71.97 to 62.2	-70.21 to 70.28	-74.57 to 45.37
	SE(D)±	0.26	0.30	0.30	0.30	0.30	1.08	1.25	1.25	1.25	1.25
	CD 5%	0.55	0.63	0.63	0.63	0.63	2.23	2.58	2.58	2.58	2.58
	CD 1%	0.75	0.86	0.86	0.86	0.86	3.03	3.50	3.50	3.50	3.50

Note: * Significant at 5% level of significance, ** Significant at 1% level of significance

Where, H_{3a} - Standard heterosis over check Virat

H_{3b} - Standard heterosis over check PKV kabuli-4

H_{3c} - Standard heterosis over check PKV kabuli-2

Table 4.11: Promising crosses on the basis of yield performance, standard heterosis, gca effects and sca effects

Sr.no	Crosses	seed yield per plant (g)	Standard heterosis (%)			SCA effects	GCA effects of parent	Significant gca effects for othe characters in desirable direction	Significant sca effects for other characters in desirable direction
			Virat (H_{3a})	PKV Kabuli-4(H_{3b})	PKV Kabuli-2 (H_{3c})				
1	PKV Kabuli-2 x Shubhra	24.35	48.48**	70.28**	45.37**	3.33**	3.96** x 3.17** H H	P_1 : 1,3,6,7,10 P_2 : 3,5,6,9,10	5,6,10
2	PKV Kabuli-2 x BDNGK-798	20.55	25.30**	43.71**	22.69**	1.80	3.96** x 0.90 H L	P_1 : 1,3,6,7,10 P_2 : 4,5,6,8,	5,6,

H : High gca L : Low gca

P_1 & P_2 : Female parent and male parent of the concerned cross, respectively

* : Significant at 5% level of significance

** : Significant at 1% level of significance

1 Days to 50% flowering 2 Days to maturity

3 plant height 4 Number of primary branches

5 Number of secondary branches 6 number of pods per plant

7 100 seed weight 8 number of seeds per pod

9 number of empty pods per plant 10 seed yield per plant.

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