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Studies on heterosis for yield attributing traits in green gram (*Vigna radiata* (L.) Wilczek)

MS Bichukale, JP Devmore, PB Vanave, TJ Bedse, MP Gawai and BD Waghmode

Abstract
To determine the degree of heterosis over the mid parent, over the better parent, and over the standard check (economic heterosis) for grain yield per plant, a study using a Line x Tester Mating Design with ten different genotypes of green gram (*Vigna radiate* L. Wilzeck) along with one check and their 24 F1 hybrids was conducted. For grain production per plant and other yield components, the cross ML-2333 x TARM-1 showed the highest average heterosis (48.61%), heterobeltiosis (28.78%), and SH (99.67%). The hybrid ML-2333 x TARM-1 registered the greatest SH for grain yield per plant (99.67%) followed by NVL-641 x TARM-1 (80.13%). Days to flowering and days to maturity had low heterosis values, whereas other characters had intermediate heterosis values. The crosses, ML-2333 x TARM-1, NVL-641 x TARM-1, PUSA-1477 x TARM-1, ML-2056 x TARM-1 and ML-2056 x Karjat local were found to be the most promising combination for most of the yield contributing traits.

Keywords: *Vigna radiata*, relative heterosis, heterobeltiosis and SH

Introduction
One of the most significant edible legumes in South and Southeast Asia, including India, is the green gram (*Vigna radiata* L. Wilczek. India produces the majority of the world's mung beans, accounting for 75% of total production. It is India's third-most significant pulse crop, behind chickpea and pigeon pea, and is regarded as one of the toughest. Green gram is a fantastic source of 25% high-quality, highly digestible protein. It has the ability to fix atmospheric nitrogen (30–40 kg N/ha), as it is a leguminous crop. Additionally, it aids in halting soil erosion. Since it only lasts a short time, it works effectively in many intense crop rotations. With a yield of 1.60 million tonnes and a productivity of 418 kg/ha, it is grown on an area of 3.83 million hectares in India. During 2015–16, green gram was grown on 3.83 lakh hectares in Maharashtra, where it produced 0.72 lakh tonnes with an average productivity of 534.7 kg/ha (Directorate of Economics and Statistic Ministry of Agriculture and Farmers Welfare 2015–16).

The F_1 hybrids can be employed for commercial purposes or for choosing promising recombinants in succeeding generations so that the best variety is released after homozygosity has been achieved. The degree of heterosis for grain yield affects the commercial utilisation of hybrid vigour. Despite being a self-pollinated crop, green gram has plenty of potential for heterosis to increase productivity. Keeping in view the above perspectives, the present study was made to know the magnitude of heterosis over mid parent, better parent and standards parent for seed yield and its components traits in elite Indian green gram genotypes.

Materials and Methods
The experimental material included 10 parents (TARM-2, PUSA-147, NVL-641, ML-2333, PUSA-1477, ML-2056, TARM-1, PKVAKM-04, Karjat local, and DGG-03), as well as a standard check (DPLM-26), which were crossed in a line x tester form to create 24 F1's. At the research farm, Department of Agriculture Botany, College of Agriculture, Dapoli, during Rabi 2017–18, the resulting 24 hybrids and their ten parents were assessed using a Randomised Block Design with three replications. Each genotype was cultivated with 30 cm between plants in two rows. To raise a healthy crop, the suggested agronomic and plant protection practices were used. For quantitative features, such as days to 50% flowering, days to maturity, plant height, and number of branches per plant, cluster per plant, pods per cluster, number of pods per plant, pod length (cm), number of grains per pods, 100-seed weight (gm) and grain yield

per plant (gm). Observations were made on five randomly selected competing plants in the parents and their hybrids. Data were subjected to analysis of variance for mean performance (Panse and Sukhatme, 1978) [9] and the hybrid performance (%) tested in comparison with mean value of two parents (Relative heterosis/RH), better parent (heterobeltiosis/BPH) and standard check (SH/SH) as per suggested by Briggle (1963) [2], Fonseca and Patterson (1968) [5] and Meredith and Bridge (1972), respectively.

Results and Discussion

Table No. 1 displays the findings from the variance analysis of parents and crosses for yield and qualities that contribute to yield. With the exception of days to 50% flowering, branches per plant, pods per cluster, and pods per plant, the analysis indicated substantial differences in the parents of all the characters, showing a sizable level of variability among the parents for the various characters under consideration. Except for branches per plant, pods per plant, and grains per pod, all of the characters were significantly different between the crossings, indicating that most of the attributes varied between the crosses. Except for the hundred seed weight, comparisons between parents and crosses were significant for other characteristics.

In terms of F_1 over mid parent, better parent, and standard check used for comparison, heterosis is stated as a percent increase or reduction. The purpose of this study was to identify the crossings with the highest heterotic potential and separate them for further analysis and commercial cultivation. The performance of the crosses was compared with that standard check parent, "DPLM-26," in terms of the amplitude of SH. The RH, BPH and SH for all the characters tested and shown in Tables 2, 3, and 4 were calculated in order to form a solid conclusion about the degree of heterosis for the eleven characters in the green gram. All three types of heterosis were observed to have a substantial negative effect on days to 50% blooming. The three best hybrids, according to heterosis for days to 50% blooming, were ML-2333 x DGG-03 (-20.30%), ML-2333 x Karjat local (-19.55%), and NVL-641 x DGG-03 (-18.05%) since they demonstrated considerable negative heterosis over the standard parent (DPLM-26). The three best hybrids for days to maturity were TARM-2 x TARM-1 (-19.63%), ML-2333 x TARM-1 (- 19.54%), and NVL-641 x TARM-1 (-18.70%). These three hybrids significantly outperformed their normal parent. Early flowering is a desired quality in green gram. Patel *et al*. (2017) [10], Reddy *et al*. (2016) [7], and Purohit *et al*. (2017) [10] reported negative estimates of heterosis for days to 50% flowering and days to maturity.

Positive heterosis is desirable for plant height in green gram. The heterotic effects for plant height were noticed in both the directions while considering RH, BPH and SH. Out of 24 hybrids, ten hybrids showed positive significant effect over the RH. The RH ranged from -5.63 percent (PUSA-1472 x PKVAKM-04) to 20.35 percent (TARM-2 x TARM-1). The hybrids TARM-2 x TARM-1 (20.35%) exhibited highest positive significant heterosis followed by ML-2056 x Karjat local (19.52%), TARM-2 x DGG-03 (16.54%), PUSA-1477 x TARM-1 (16.44%) and NVL-641 x DGG-03 (-16.44%). Only two hybrids showed positive significant effect over its better parent. Crosses, ML-2333 x Karjat local (15.14%) showed highest significant positive heterosis over better parent followed by NVL-641 x DGG-03 (13.70%). The heterobeltiosis was ranged from –9.82% (ML-2333 x PKVAKM-04) to 15.14% (ML-2333 x Karjat local). Sixteen hybrids showed positive significant heterotic effect over standard check parent DPLM-26. The SH ranged from 4.85 percent (TARM-2 x Karjat local) to 33.80 percent (PUSA-1477 x TARM-1). Hybrid PUSA-1477 x TARM-1 (33.80%) exhibited highest positive significant heterotic effect followed by PUSA-1477 x DGG-03 (30.16%), PUSA-1472 x DGG-03 (26.69%), NVL-641 x DGG-03 and PUSA-1477 x PKVAKM-04 (23.05%). The results revealed that hybrids were found to be taller than mean of better parent and standard check parent (DPLM-26). This result agrees with Kumar and Prakash (2011) [6] and Choudhary *et al*. (2016) [3].

The significant heterotic effects for branches per plant were noticed in positive direction among all the three type of heterosis. The range of RH for branches per plant was observed from 8.86 percent (PUSA-1477 x Karjat local) to 48.72 percent (ML-2333 x TARM-1). Among all the hybrids, fifteen hybrids exhibited positive significant heterotic effects over RH. Hybrids ML-2333 x TARM-1 (48.72%) showed highly positive significant heterotic effect followed by TARM-2 x PKVAM-04 (47.22%), PUSA-1472 x PKVAKM-04 (44.44%), PUSA-1472 x Karjat local (39.47%) and PUSA-1472 x DGG-03 (37.84%). In case of heterobeltiosis, out of twenty four hybrids only eight hybrids showed positive significant heterotic effects. The range of BPH was from 4.88 percent (PUSA-1477 x Karjat local) to 43.24 percent (TARM-2 x PKVAKM-04). The hybrid, TARM-2 x PKVAKM-04 (43.24%) exhibited highest heterobeltiosis followed by PUSA-1472 x PKVAKM-04 (40.54%), ML-2056 x PKVAKM-04 (35.14%) and TARM-2 x DGG-03 (33.33%). Among the 24 hybrids eighteen hybrids exhibited positive significant over heterotic effect over the standard check parent (DPLM-26). SH ranged from 19.44 percent (PUSA-1477 x Karjat local) to 61.11 percent (ML-2333 x TARM-1). The hybrid ML-2333 x TARM-1 (61.11%) recorded highest significant SH followed by PUSA-1477 x TARM-1 (55.56%), NVL-641 x TARM-1 (50.00%), TARM-2 x PKVAKM-04 (47.22%) and PUSA-1472 x PKVAKM-04 (44.44%). This result is in agreement with Kumar and Prakash (2011) [6] and Purohit *et al*. (2017) [10].

The significant heterotic effects for number of clusters per plant were noticed in both the direction for average heterosis and heterobeltiosis while only significant positive heterotic effects were observed in SH. The RH for this character ranged from -33.92 percent (TARM-2 x TARM-1) to 52.97 percent (PUSA-1477 x Karjat local). Out of 24 hybrids, nine hybrids exhibited positive heterosis while two hybrids with negative significant over the RH for this trait. The hybrids PUSA-1477 x Karjat local (52.97%) showed highest positive significant heterotic effects for this trait followed by NVL-641 x TARM-1 (50.00%), NVL-641 x DGG-03 (47.37%), ML-2333 x TARM-1 (45.15%), PUSA-1472 x PKVAKM-04 (43.18%), NVL-641 x PKVAKM-04 (40.37%) and PUSA-1472 x Karjat local (39.18%). Among 24 hybrids, three hybrids showed positive heterobeltiosis while two hybrids noticed negative heterobeltiosis over the better parent. Heterobeltiosis ranged from – 40.00 percent (TARM-2 x TARM-1) to 37.60 percent (ML-2333 x TARM-1). The hybrid ML-2333 x TARM-1 (37.60%) recorded highest significant positive heterobeltiosis followed by PUSA-1477 x Karjat local (34.33%) and PUSA-1472 x PKVAKM-04 (34.04%). SH ranged from -21.88 percent (TARM-2 x TARM-1) to 79.17 percent (ML-2333 x

TARM-1). Out of 24 hybrids, six hybrids found significant positive SH over the check (DPLM-26). The hybrid ML-2333 x TARM-1 (79.17%) recorded highest significant positive SH followed by NVL-641 x TARM-1 (50.00%), ML-2333 x Karjat local (41.67%) and PUSA-1477 x Karjat local (40.63). Similar findings were observed by Patel *et al*. (2017) [10], Yadhav *et al*. (2015) [13].

The RH for number of pods per cluster was ranged from -3.57 percent (PUSA-1477 x TARM-1) to 38.18 percent (ML-2333 x TARM-1). Out of 24 hybrids, eight hybrids exhibited positive significant RH for this trait. Maximum RH was found in the hybrid ML-2333 x TARM-1 (38.18%) followed by ML-2333 x Karjat local (31.37%), NVL-641 x TARM-1 (29.52%) and NVL-641 x DGG-03 (24.21%). The range of BPH was observed from –10.00 percent (PUSA-1477 x TARM-1) to 28.85 percent (ML-2333 x PKVAKM-04). Among 24 hybrids, two hybrids noticed significant positive heterosis over better parent. Hybrid ML-2333 x PKVAKM-04 (28.85%) observed maximum BPH followed by ML-2333 x TARM-1 (26.67%). Thirteen hybrids exhibited positive significant heterotic effects over the standard check and ranged from 6.38 percent (PUSA-1477 x DGG-03) to 61.70 percent (ML-2333 x TARM-1). The hybrid, ML-2333 x TARM-1 (61.70%) showed highest significant positive SH followed by NVL-641 x TARM-1 (44.68%), ML-2333 x PKVAKM-04, PUSA-1472 x TARM-1 (42.55%) and ML-2056 x TARM-1 (36.17%). These results confirmed with the results of Yadav *et al.* (2015) [13] and Narsimhulu *et al*. (2016) [7].

Among the 24 hybrids, six hybrids exhibited positive significant RH for pods per plant. The range of RH was observed from -15.28 percent (TARM-2 x TARM-1) to (50.95%) NVL-641 x Karjat local. Hybrid, NVL-641 x Karjat local (50.95%) was noticed maximum RH followed by ML-2333 x TARM-1 (31.94%), NVL-641 x TARM-1 (28.78%) and PUSA-1472 x PKVAKM-04 (25.90%). The range of BPH observed from –15.65 percent (TARM-2 x TARM-) to 41.42 percent (NVL-641 x Karjat local). Among the 24 hybrids, three hybrids recorded significant positive BPH. The hybrid NVL-641 x Karjat local (41.42%) exhibited highest heterobeltiosis followed by ML-2333 x TARM-1 (27.15%), ML-2056 x Karjat local (22.86%) and PUSA-1472 x PKVAKM-04 (17.25%). SH over the check parent (DPLM-26) ranged from –13.95 percent (PUSA-1477 x DGG-03) to 40.36 percent (ML-2333 x TARM-1). Out of 24 hybrids, two hybrids recorded significant positive heterosis for this trait. Among the hybrids ML-2333 x TARM-1 (40.36%) recorded highest significant positive SH followed by NVL-641 x Karjat local (29.67%). Similar results were also reported by Yadav *et al.* (2015) [13], Narsimhulu *et al*. (2016) [7] and Purohit *et al.* (2017) [10].

The heterotic effects for pod length were noticed in positive direction among all three type of heterosis. Out of 24 hybrids, six hybrids showed significant positive heterosis over mid parent for this trait. The RH range for pod length observed from -7.97 percent (TARM-2 x Karjat local) to 32.80 percent (ML-2333 x DGG-03). The hybrid ML-2333 x DGG-03 (32.80%) recorded highest significant positive RH followed by PUSA-1472 x DGG-03 (25.80%), PUSA-1477 x DGG-03 (21.47%) and ML-2333 x TARM-1 (19.12%). The range of BPH noticed from –27.22 percent (TARM-2 x Karjat local) to 22.43 percent (ML-2333 x DGG-03). Among 24 hybrids, two hybrids showed significant positive BPH. Hybrid ML-2333 x DGG-03 (22.43%) recorded highest significant positive BPH followed by PUSA-1472 x DGG-03 (22.00%). Among 24 hybrids, twelve hybrids exhibited positive significant heterotic effect over the standard check (DPLM-26) and ranged from 4.10 percent (ML-2333 x PKVAKM-04) to 61.19 percent (NVL-641 x Karjat local). The hybrid, NVL-641 x Karjat local (61.19%) showed highest significant positive SH followed by ML-2333 x Karjat local (50.47%) and PUSA-1477 x Karjat local (47.39%). The present results were in close association with the finding reported by Patel *et al*. (2017) [10], Narsimhulu *et al*. (2016) [7], Choudhary *et al.* (2016) [3] and Purohit *et al*. (2017) [10] in green gram.

For grains per pod, eight hybrids showed significant positive heterosis over mid parent. The heterosis over mid parent was ranged from -3.27 percent (TARM-2 x PKVAKM-04) to 27.34 percent (ML-2333 x DGG-03). The hybrid, ML-2333 x DGG-03 (27.34%), TARM-2 x DGG-03 (18.90%) and ML-2333 x TARM-1 (17.76%) recorded highest significant positive RH. The range of BPH observed from -8.47 percent (TARM-2 x Karjat local (ML-2056 x Karjat local) to 21.23 percent (ML-2333 x DGG-03). Among 24 hybrids, two hybrids showed positive BPH. The hybrid, ML-2333 x DGG-03 (21.23%) exhibited highest positive BPH followed by TARM-2 x DGG-03 (18.49%). Eleven hybrids exhibited positive significant heterotic effect over the standard check and ranged from 1.34 percent (TARM-2 x PKVAKM-04) to 22.60 percent (NVL-641 x Karjat local, NVL-641 x PKVAKM-04, NVL-641 x TARM-1). The hybrids NVL-641 x Karjat local, NVL-641 x PKVAKM-04, NVL-641 x TARM-1 (22.60%), observed highest positive significant SH followed by PUSA-1472 x TARM-1, PUSA-1477 x Karjat local (21.92%) and PUSA-1472 x Karjat local (21.23%). These results were in agreement with the findings of Reddy *et al*. (2016) [7], Kumar and Prakash (2011) [6], Sathya and Jayanami (2011) [12] and Yadav *et al*. (2015) [13] for grains per pod in green gram.

For the trait, hundred seed weight, none of hybrids was showed positive significant heterosis over mid parent and ranged from -15.00 percent (TARM-2 x PKVAKM-04) to 18.31 percent (ML-2056 x TARM-1). The hybrids ML-2056 x TARM-1 (18.31%) exhibited highest positive RH followed by ML-2056 x DGG-03 (16.97%), PUSA-1477 x DGG-03 (15.43%) and NVL-641 x PKVAKM-04 (11.19%). The BPH ranged from –28.44 percent (PUSA-1472 x Karjat local) to 17.48 percent (ML-2056 x TARM-1). Among 24 hybrids, none of hybrids was showed positive significant heterosis while seven hybrids found negative significant heterosis over the better parent. The hybrid, ML-2056 x TARM-1 (17.48%) showed highest positive heterosis over better parent followed by NVL-641 x PKVAKM-04 (9.66%) and ML-2056 x PKVAKM-04 (5.52%). SH over the check parent (DPLM-26) ranged from -9.85 percent (TARM-2 x PKVAKM-04) to 46.21 percent (ML-2056 x DGG-03). Out of 24 hybrids, seven hybrids were found positive significant heterosis for hundred seed weight over the check (DPLM-26). The hybrid ML-2056 x DGG-03 (46.21%) showed maximum positive significant heterosis over the standard check followed by PUSA-1477 x DGG-03 (41.67%) and ML-2333 x DGG-03 (33.33%) and ML-2056 x Karjat local (30.30%). High mangnitude of desirable heterosis for the trait was also reported by Sathya and Jayanmi (2011) [12] and Choudhary *et al*. (2016) [3].

The significant heterotic effects for grain yield per plant were noticed in positive direction only while considering heterosis over parental mean, better parent and check parent. In case of average heterosis, out of 24 hybrids, four hybrids showed significant positive heterotic effects *viz*., ML-2333 x TARM-1 (48.61%), NVL-641 x TARM-1 (41.18%), PUSA-1477 x TARM-1 (34.72%) and PUSA-1477 x DGG-03 (25.35%). The heterosis over mid parent for grain yield per plant was ranged from -15.67 percent (TARM-2 x TARM-1) to 48.61 percent (ML-2333 x TARM-1). The hybrids ML-2333 x TARM-1 (46.61%) was recorded highest significant positive heterosis followed by NVL-641 x TARM-1 (41.18%), PUSA-1477 x TARM-1 (34.72%) and PUSA-1477 x DGG-03 (25.35%). The BPH ranged from -22.69 percent (TARM-2 x TARM-1) to 28.78 percent (ML-2333 x TARM-1). Out of 24 hybrids, only one hybrid, ML-2333 x TARM-1 (28.78%) exhibited highest positive BPH. Among 24 hybrids, eighteen hybrids exhibited positive significant heterotic effect over the standard check, (DPLM-26) and ranged from 19.87% (TARM-2 x TARM-1) to 99.67 percent (ML-2333 x TARM-1). The hybrids ML-2333 x TARM-1 (99.67%) recorded highest significant positive SH followed by NVL-641 x TARM-1 (80.13%), PUSA-1477 x TARM-1 (78.83%), ML-2056 x TARM-1 (70.03%) and ML-2056 x Karjat local (67.43%). Such high significant positive SH also reported by Shrivastava and Singh (2013) [11] and Choudhary *et al*. (2016) [3] for grain yield per plant in green gram.

Table 1: Analysis of variance of parents and crosses in Line x Tester analysis for eleven characters of green gram.

Characters	Mean sum of squares (d.f)								
	Repl (2)	Tret (33)	P (9)	L(5)	T(3)	L vs. T (1)	P vs. C (1)	Crosses (23)	Error (66)
Days to 50% Flowering	0.42	19.73**	2.06	0.80	3.78*	3.20	488.47**	6.26**	1.23
Days to maturity	1.08	16.94**	12.46**	5.51	19.37**	26.45**	133.83**	13.61**	2.38
Plant height (cm)	5.68	34.79**	44.15**	50.29**	48.60**	0.09	276.99**	20.60*	11.17
Branches per plant	0.34	0.55**	0.18	0.13	0.16	0.47	12.02**	0.20	0.20
Clusters per plant	2.34	7.16**	4.42**	4.08*	3.92*	7.65*	25.19**	7.45**	1.24
Pods per clusters	0.43	0.54**	0.19	0.12	0.25	0.32	6.12**	0.44*	0.24
Pods per plant	2.26	24.13**	11.65	17.44*	3.63	6.81	86.60**	26.30	7.01
Pod length (cm)	2.67	4.86**	6.20**	2.42	9.79**	14.37	23.68**	3.51**	1.06
Grains per pod	1.84	2.37**	3.45**	2.27*	2.52*	12.17**	23.69**	1.02	0.86
Hundred seed weight (g)	1.41	1.50**	2.11**	0.08	3.69**	7.52**	0.01	1.32**	0.46
Grain yield per plant (g)	0.56	15.63**	14.64**	4.96	8.90	80.23**	103.23**	12.22**	5.30

* Significant at 5% level, ** Significant at 1% level

Table 2: Heterosis (%) over mid parent, better parent and standard check for days to 50% flowering, Days to maturity, plant height, branches / plant pod / cluster, for 24 hybrids.

Sr. no	Hybrids	Days to 50% flowering			Days to maturity			Plant height (cm)			Branches per plant		
		MP	BP	SC	MP	BP	SC	MP	BP	SC	MP	BP	SC
1	TARM-2 x TARM-1	-12.16**	-12.50**	-15.79**	-5.86**	-7.95**	-19.63**	20.35**	12.40	19.41**	20.00	6.67	33.33*
2	TARM-2 x PKVAKM-04	-11.37**	-11.72**	-15.04**	-4.32*	-4.77*	-16.85**	6.40	-6.54	13.86	47.22**	43.24**	47.22**
3	TARM-2 x Karjat local	-12.10**	-14.14**	-18.05**	-1.69	-1.90	-13.98**	11.11	8.62	4.85	26.32*	17.07	33.33*
4	TARM-2 x DGG-03	-11.02**	-11.02**	-15.04**	-5.37**	-7.75**	-15.19**	16.54*	7.09	17.85*	40.54**	33.33*	44.44**
5	PUSA-1472 x TARM-1	-13.73**	-14.06**	-17.29**	-1.12	-4.55*	-14.44**	6.97	2.86	18.37	30.00*	15.56	44.44**
6	PUSA-1472 x PKVAKM-04	-14.51**	-14.84**	-18.05**	-1.05	-2.79	-12.87**	-5.63	-8.25	11.79	44.44**	40.54**	44.44**
7	PUSA-1472 x Karjat local	-8.06**	-10.24**	-14.29**	-2.35	-3.41	-13.43**	6.96	-1.66	13.17	39.47**	29.27*	47.22**
8	PUSA-1472 x DGG-03	-7.87**	-7.87**	-12.03**	-0.76	-2.01	-9.91**	12.55*	10.09	26.69**	37.84**	30.77*	41.67**
9	NVL-641 x TARM-1	-13.73**	-14.06**	-17.29**	-5.74**	-8.73**	-18.70**	10.89	10.44	17.33*	24.14*	20.00	50.00**
10	NVL-641 x PKVAKM-04	-9.80**	-10.16**	-13.53**	-3.59*	-4.99*	-15.37**	-2.36	-8.96	10.92	13.92	7.14	25.00
11	NVL-641 x Karjat local	-11.29**	-13.39**	-17.29**	-4.56*	-5.30**	-15.65**	11.76	7.07	12.82	20.48	19.05	38.89*
12	NVL-641 x DGG-03	-14.17**	-14.17**	-18.05**	-6.91**	-8.36**	-15.74**	16.17**	13.70*	25.13**	18.52	14.29	33.33*
13	ML-2333 x TARM-1	-17.84**	-14.84**	-18.05**	-7.16**	-10.50**	-19.54**	1.04	-0.63	9.19	48.72**	28.89*	61.11**
14	ML-2333 x PKVAKM-04	-12.50**	-12.50**	-15.79**	-5.09**	-6.90**	-16.30**	-5.16	-9.82	9.88	28.57*	21.62	25.00
15	ML-2333 x Karjat local	-14.06**	-16.41**	-19.55**	-7.19**	-8.34**	-17.59**	16.04*	8.99	19.76**	21.62	9.76	25.00
16	ML-2333 x DGG-03	-16.86**	-17.19**	-20.30**	-7.94**	-8.96**	-16.30**	5.91	5.83	16.46*	25.00	15.38	25.00
17	PUSA-1477 x TARM-1	-4.69*	-4.69*	-8.27**	-1.69	-6.42**	-13.61**	16.44**	8.27	33.80**	34.94**	24.44*	55.56**
18	PUSA-1477 x PKVAKM-04	-7.81**	-7.81**	-11.28**	1.40	-1.81	-9.35**	0.28	-0.42	23.05**	20.00	18.42	25.00
19	PUSA-1477 x Karjat local	-4.42*	-7.03**	-10.53**	-3.91*	-6.32**	-13.52**	6.77	-4.91	17.50*	8.86	4.88	19.44
20	PUSA-1477 x DGG-03	-7.45**	-7.81**	-11.28**	-2.21	-2.41	-9.91**	11.42*	5.33	30.16**	24.68*	23.05	33.33*
21	ML-2056 x TARM-1	-13.51**	-14.50**	-15.79**	-3.22	-7.75**	-15.09**	13.84*	12.72	19.76**	17.07	6.67	33.33*
22	ML-2056 x PKVAKM-04	-15.83**	-16.79**	-18.05**	-2.18	-5.13**	-12.69**	1.84	-5.55	15.08*	35.14**	35.14*	38.89*
23	ML-2056 x Karjat local	-9.52**	-12.98**	-14.29**	-3.45*	-5.73**	-13.24**	19.52**	15.14*	19.93**	30.77*	24.39	41.67**
24	ML-2056 x DGG-03	-6.98**	-8.40**	-9.77**	-1.46	-1.51	-9.35**	14.56*	11.50	22.70**	26.32*	23.08	33.33*

*, ** - Significant at 5% and 1% respectively

Table 3: Heterosis (%) over mid parent, better parent and standard check for cluster/pod, pod / cluster, pods / plant and pod length for 24 hybrids.

Sr. no	Hybrids	Clusters per plant			Pod per cluster			Pods per plant			Pod length (cm)		
		MP	BP	SC	MP	BP	SC	MP	BP	SC	MP	BP	SC
1	TARM-2 x TARM-1	-33.92**	-40.00**	-21.88	2.65	-3.33	23.40	-15.28	-15.65	-13.65	7.20	1.82	4.20
2	TARM-2 x PKVAKM-04	-10.20	-13.73	-8.33	21.90*	20.75	36.17**	-5.70	-5.70	-4.30	2.09	-8.97	7.00
3	TARM-2 x Karjat local	-23.95*	-24.51	-19.79	14.02	12.96	29.79*	-2.92	-2.05	-0.59	-7.97	-27.22**	15.21
4	TARM-2 x DGG-03	5.88	-2.94	3.13	12.62	9.43	23.40	-3.89	-5.99	-4.60	15.94	7.33	16.04
5	PUSA-1472 x TARM-1	-3.38	-20.00	4.17	19.64*	11.67	42.55**	21.09*	12.32	14.99	9.88	9.48	12.03
6	PUSA-1472 x PKVAKM-04	43.18**	34.04*	31.25*	15.38	15.38	27.66*	25.90**	17.25	18.99	4.73	-2.38	14.74
7	PUSA-1472 x Karjat local	39.18**	26.34	32.29*	15.09	12.96	29.79*	15.56	12.94	3.56	10.70	-9.13	43.84**
8	PUSA-1472 x DGG-03	2.99	1.18	-10.42	21.57*	19.23	31.91*	13.83	8.26	5.04	25.80*	22.00**	31.90**
9	NVL-641 x TARM-1	50.00**	15.20	50.00**	29.52**	13.33	44.68**	28.78**	14.78	17.51	15.01	5.73	29.01*
10	NVL-641 x PKVAKM-04	40.37**	20.21	17.71	17.53	9.62	21.28	1.63	-9.06	-7.72	12.62	10.55	34.89**
11	NVL-641 x Karjat local	12.24	-6.47	2.08	23.23*	12.96	29.79*	50.95**	41.42**	29.67**	15.01*	1.83	61.19**
12	NVL-641 x DGG-03	47.37**	31.76	16.67	24.21*	18.00	25.53	9.21	-0.31	-3.26	13.01	6.57	30.04*
13	ML-2333 x TARM-1	45.15**	37.60**	79.17**	38.18**	26.67*	61.70**	31.94**	27.15**	40.36**	19.12	12.67	15.30
14	ML-2333 x PKVAKM-04	10.68	1.79	18.75	31.37**	28.85*	42.55**	-6.02	-9.81	-0.45	-0.27	-1143	4.10
15	ML-2333 x Karjat local	28*	21.43	41.67**	15.38	11.11	27.66**	8.66	-0.54	9.79	20.60*	-4.95	50.47**
16	ML-2333 x DGG-03	0.51	-11.61	3.13	18.00	18.00	25.53	-8.44	-13.98	-5.04	32.80**	22.43*	32.37**
17	PUSA-1477 x TARM-1	19.40	4.00	25.00	-3.57	-10.00	14.89	13.27	6.38	8.90	15.50	10.03	12.59
18	PUSA-1477 x PKVAKM-04	37.65**	24.47	21.88	11.54	11.54	23.40	7.44	1.32	2.82	4.66	-6.43	9.98
19	PUSA-1477 x Karjat local	52.97**	34.33*	40.63**	13.21	11.11	27.66**	16.01	14.89	5.34	17.47*	-6.89	47.39**
20	PUSA-1477 x DGG-03	18.01	11.76	-1.04	-1.96	-3.85	6.38	-7.94	-11.31	-13.95	21.47*	12.77	21.92
21	ML-2056 x TARM-1	-19.50	-35.60**	-16.15	13.27	6.67	36.17**	4.24	-0.29	2.08	16.07	11.40	23.97*
22	ML-2056 x PKVAKM-04	26.63	13.83	11.46	-2.86	-3.77	8.51	1.37	-2.63	-1.19	1.43	-1.27	16.04
23	ML-2056 x Karjat local	-2.56	-14.93	-10.94	2.80	1.85	17.02	24.04*	22.86*	14.84	-6.78	-20.62**	25.65*
24	ML-2056 x DGG-03	18.75	11.76	-1.04	4.85	1.89	14.89	-5.45	-7.19	-9.94	16.92	15.26	28.26*

*, ** - Significant at 5% and 1% respectively

Table 4: Heterosis (%) over mid parent, better parent and standard parent for Grain per pod, Grain yield per plant(g) and Hundred seed weight (g) for 24 hybrids

Sr. No.	Hybrid	Grains per pod			Hundred seed weight (g)			Grain yield per plant		
		MP	BP	SC	MP	BP	SC	MP	BP	SC
1	TARM-2 x TARM-1	2.84	-5.23	11.64	-8.70	-10.64	-4.55	-15.67	-22.69	19.87
2	TARM-2 x PKVAKM-04	-3.27	-8.07	1.34	-15.00	-17.93	-9.85	-0.80	-1.21	27.69
3	TARM-2 x Karjat local	0.62	-8.47	10.96	-9.46	-25.57**	18.18	-10.52	-20.95	33.22
4	TARM-2 x DGG-03	18.90**	18.49*	18.49*	-11.80	-24.06**	7.58	6.02	-0.66	46.91*
5	PUSA-1472 x TARM-1	15.96*	3.49	21.92**	-7.58	-9.22	-3.03	13.48	-0.84	53.75**
6	PUSA-1472 x PKVAKM-04	14.19*	4.97	15.75	-3.20	-6.21	3.03	6.75	1.65	30.29
7	PUSA-1472 x Karjat local	13.46*	0.01	21.23**	-13.19	-28.44**	13.64	15.42	-2.59	64.17**
8	PUSA-1472 x DGG-03	11.03	6.85	6.85	-0.93	-14.44	21.21	10.88	-1.10	46.25*
9	NVL-641 x TARM-1	6.55	4.07	22.60**	-13.48	-13.48	-7.58	41.18**	16.18	80.13**
10	NVL-641 x PKVAKM-04	1.54	0.61	13.01	11.19	9.66	20.45	22.70	9.28	40.07*
11	NVL-641 x Karjat local	4.99	1.13	22.60**	-2.45	-18.42*	29.55*	24.39	-0.85	67.10**
12	NVL-641 x DGG-03	9.03	3.05	15.75*	-4.88	-16.58	18.18	18.20	-0.88	46.58*
13	ML-2333 x TARM-1	17.76**	4.07	22.60**	1.73	-0.68	11.36	48.61**	28.78*	99.67**
14	ML-2333 x PKVAKM-04	7.85	-1.86	8.22	5.12	4.05	16.67	21.75	14.87	47.23*
15	ML-2333 x Karjat local	13.92*	-0.56	20.55*	-4.92	-18.89*	28.79*	8.49	-9.16	53.09**
16	ML-2333 x DGG-03	27.34**	21.23**	21.23**	5.07	-5.88	33.33*	19.05	5.29	55.70**
17	PUSA-1477 x TARM-1	7.49	-4.07	13.01	-5.04	-6.38	0.01	34.72**	15.34	78.83**
18	PUSA-1477 x PKVAKM-04	9.46	0.62	10.96	-0.71	-3.45	6.06	7.85	0.38	28.66
19	PUSA-1477 x Karjat local	14.10*	0.56	21.92**	-10.56	-26.05*	17.42	4.16	-13.80	45.28*
20	PUSA-1477 x DGG-03	13.17	8.90	8.90	15.43	0.01	41.67**	25.35*	9.47	61.89**
21	ML-2056 x TARM-1	5.49	0.58	18.49*	18.31	17.48	27.27*	17.51	9.66	70.03**
22	ML-2056 x PKVAKM-04	2.21	0.62	10.96	6.25	5.52	15.91	20.36	17.60	57.98**
23	ML-2056 x Karjat local	-2.70	-8.47	10.96	-2.44	-17.94*	30.30*	10.56	-0.66	67.43**
24	ML-2056 x DGG-03	10.60	7.05	14.96	16.97	3.21	46.21**	-12.05	-16.08	24.10

*, ** - Significant at 5% and 1% respectively

Table 5: The list of promising hybrids based on per see performance, SH (SH).

Sr. No	Superior crosses	ML-2333 × TARM-1		NVL-641 x TARM-1		PUSA-1477 x TARM-1		ML-2056 x TARM-1		ML-2056 x Karjat local	
		Mean	SH	Mean	SH	Mean	SH	Mean	SH	Mean	SH
1	Days to 50% flowering	36.33	-18.05**	36.67	-17.29**	40.67	-8.27**	37.33	-15.79**	38.00	-14.29**
2	Days to maturity	57.93	-19.54**	58.53	-18.70**	62.20	-13.61**	61.13	-15.09**	62.87	-13.24**
3	Plant height (cm)	42.00	9.19	45.13	17.33*	51.47	33.80**	46.07	19.76**	46.13	19.93**
4	Branches per plant	3.87	61.11**	3.60	50.00**	3.73	55.56**	3.20	33.33*	3.40	41.67**
5	Cluster per plant	11.47	79.17**	9.60	50.00**	8.00	25.00	5.37	-16.15	5.70	-10.94
6	Pods per cluster	5.07	61.70**	4.53	44.48**	3.60	14.89	4.27	36.17**	3.67	17.02
7	Pods per plant	31.53	40.36**	26.40	17.51	24.46	8.90	22.93	2.08	25.80	14.84
8	Pod length (cm)	8.24	15.30	9.22	29.01*	8.04	12.59	8.86	23.97*	8.98	25.65*
9	Grains per pod	11.93	22.60**	10.93	22.60**	11.00	13.01	11.53	18.49*	10.80	10.96
10	Hundred seed weight (g)	4.90	11.36	4.06	-7.58	4.40	0.00	5.60	27.27*	5.73	30.30*
11	Grain yield per plant (g)	20.43	99.67**	18.43	80.13**	18.30	78.83**	17.40	70.03**	17.13	67.43**

* Significant at 5% level of significance and

** Significant at 1% level of significance

Conclusion

With the exception of hundred seed weight, which indicated the presence of heterotic combination, all the yield-contributing parameters displayed significant mean squares attributable to hybrids vs. parents. Ml-2056 and TARM-2 outperformed the other lines in terms of mean performance for the majority of the characters, including grain yield per plant, pods per cluster, branches per plant, and clusters per plant. TARM-2 also outperformed the other lines in terms of 50% flowering and days to maturity. For the majority of the characters, Karjat local and TARM-1 showed the highest improved mean performance among the testers. The hybrid (ML-2333 x TARM-1) also demonstrated a negative standard heterotic response in the desired direction for the attributes days to 50% blooming and days to maturity. The cross combinations ML-2333 x TARM-1 (99.67%), NVL-641 x TARM-1 (80.13%), PUSA-1477 x TARM-1 (78.83%), ML-2056 x TARM-1 (70.03%), and ML-2056 x Karjat local (67.43) had the highest SH for grain yield per plant. These crosses could therefore be identified as prospective high yielders.

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