Exploitation of Heterosis in Groundnut (*Arachis hypogaea* L.): A Comprehensive Evaluation of F_1 Hybrids for Yield and Quality Traits

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Abstract

Heterosis analysis was performed in 20 F_1 s of groundnut derived from a Line × Tester mating design involving 5 lines (Dharani, Dheeraj, Kadiri Amaravathi, Narayani and Kadiri-6) and 4 testers (ICGV-06188, ICGV-171377, ICGV-95165 and Bheema) for pod yield, yield attributing and quality traits (oil, protein and sucrose). Among all the F_1 s, Kadiri-6 × ICGV-171377 showed the highest heterotic advantage in pod yield plant-1 and kernel yield plant-1 compared to the standard parent Kadiri-6 reflecting the influence of over-dominant gene action. Similarly, Narayani × ICGV-06188, Kadiri-6 × ICGV-95165 and Kadiri-6 × ICGV-171377 consistently exhibited high positive heterosis for pod yield plant-1, kernel yield plant-1, harvest index and quality para meters. while also showing desirable negative heterosis for days to flowering and maturity. Hence, these crosses represent promising heterotic combinations for further development of high-yielding and quality-improved groundnut lines through recombination breeding.

Keywords: groundnut, heterosis, quality traits and yield components

Introduction

Groundnut (*Arachis hypogaea* L.) is one of the most important oilseed and food legume crops cultivated throughout the tropical and subtropical regions of the world owing to its high economic and nutritional value. Globally, it is cultivated over an area of 30 million hectares with an annual production of about 55–56 million tonnes and an average productivity of around 1850 kg ha^{-1}. India is one of the leading groundnut-producing countries in the world, contributing significantly to the global oilseed economy. During 2025–26, it occupied nearly 5.6 million hectares with a production of about 7.5 million tonnes and productivity of approximately 1340 kg ha^{-1} [1]. Among the major growing states, gujarat ranks first in production, while Andhra Pradesh is one of the major cultivating states.

It is popularly referred as the "King of Oilseeds" because of its rich nutritional composition and economic value. The kernels contain about 45–50 % oil, 25–30 % protein, 10–12 % carbohydrates and approximately 4–8 % sucrose depending upon the genotype and environmental conditions [2]. Because of its high protein and energy value, groundnut plays a vital role in human nutrition and in combating malnutrition among children through protein-rich supplementary foods, value added products such as peanut butter, chikkis, protein bars, confectionary items, roasted snacks and ready-to-eat health foods have gained tremendous importance due to increasing awareness regarding healthy diets and balanced nutrition [3]. The relatively high sucrose content also enhances sweetness and flavour, making the kernels highly suitable for confectionary and bakery industries.

Despite its economic importance, productivity is often constrained by several biotic and abiotic stresses, narrow genetic variability and low harvest index. Therefore, development of high-yielding and quality-improved varieties has become a major objective in breeding programmes. Heterosis or hybrid vigour, which refers to the superiority of F_1 hybrids over their parents for yield and quality traits, is an effective approach for crop improvement. Estimation of heterosis helps in identifying promising cross combinations capable of producing superior segregants in advanced generations [4]. Although its commercial exploitation is more feasible in cross-pollinated crops, heterosis also plays an important role in self-pollinated crops like groundnut for selecting superior recombinants and understanding the gene action governing important traits. Hence, heterosis breeding provides valuable information about the genetic architecture of economically important traits and aids in formulating efficient breeding strategies for varietal improvement.

In the present investigation, heterosis was evaluated for important agronomic, yield and quality traits using the nationally popular variety Kadiri-6 as the standard check because of its wide adaptability, stable performance and farmer preference. whereas, for the traits *viz*., days to 50 % flowering, days to maturity, plant height and oil content considering heterosis in negative direction is desirable. This study aimed to identify superior heterotic combinations with enhanced productivity and quality traits for their effective utilization in future breeding programmes for the development of high-yielding and nutritionally superior varieties.

Materials And Methods

The base material for the present research comprised of 9 genotypes which includes 5 lines (Dharani, Dheeraj, Kadiri Amaravathi, Narayani and Kadiri-6) and 4 testers (ICGV-06188, ICGV-171377, ICGV-95165 and Bheema) with their 20 F_1s derived through hybridization in a LxT mating fashion during *kharif,* 2020 (Plate 1). The salient features of parents are presented in Table 1.

All 20 F_1 s along with their 9 parents were sown in a Randomized block design (RBD) with two replications during *rabi*, 2020 (Plate 2) at dry land farm of S.V. Agricultural College, Tirupati, ANGRAU. Each entry was sown in 2 rows of 3 mts length with a spacing of 30 cms between the rows and 10 cms between the plants. Recommended crop production and protection measures were followed to maintain good crop growth.

Observations were recorded on 5 randomly tagged competitive plants from the centre of row in each genotype in each replication for all the yield, yield components and quality traits *viz.,* plant height, number of primary branches plant^{-1}, number of secondary branches plant^{-1}, number of pods plant^{-1}, number of matured pods plant^{-1}, 100 pod weight, 100 kernel weight, sound mature kernel (%), shelling per cent, dry haulm weight plant^{-1}, pod yield plant^{-1}, kernel yield plant^{-1}, harvest index (%), oil content (%), protein content (%) and sucrose content (%) except 50 % flowering and maturity that were noted per plot basis. The mean of these 5 plants were used to compute mid parent heterosis (MH), better parent heterosis (BH) and standard heterosis (SH). Per cent mid parent heterosis (MH), better parent heterosis (BH) and standard heterosis (SH) for 18 traits were presented from Tables 2 to 7 respectively. The superiority of F_1 over the mid parent and better parent was estimated as per the formula given by [5] and [6] respectively. The significance of heterosis is tested by using t test suggested by [7] and [8].

Results and Discussion

The magnitude of heterosis varied from cross to cross for all the traits studied. Considerable heterosis observed in certain crosses, while low heterosis in others, indicated the diverse genetic background and nature of gene action among the parental combinations used in the present investigation. The estimates of mid parent heterosis (MH), better parent heterosis (BH) and standard heterosis (SH) for yield, yield contributing and quality traits among 20 F_1 s of groundnut are presented in Tables 2 to 7.

Mid parent heterosis

Mid parent heterosis is useful in identification of crosses exhibiting dominant gene effects. In the present study, the cross Dheeraj × ICGV-171377 recorded desirable and significant negative mid parent heterosis for both days to 50 % flowering and days to maturity (-13.89 % and -4.13 %, respectively). Similarly, Kadiri-6 × ICGV-95165 (-7.38 %) and Kadiri Amaravathi × Bheema (-5.66 %) exhibited desirable mid parent heterosis for early flowering, while Narayani × ICGV-06188 (-2.76 %) also showed desirable significant negative heterosis for early maturity. Hence, selection of these crosses may be useful for developing high yielding and early maturing segregants. Similar findings were earlier reported by [9], [10], [11], [12], [13] and [14].

Eight crosses exhibited significant positive mid parent heterosis for number of primary branches plant^{-1} among which Dheeraj × ICGV-95165 (52.63 %), Narayani × ICGV-95165 (40.68 %) and Kadiri-6 × ICGV-06188 (35.94 %) were superior. Significant positive heterosis for secondary branches plant^{-1} was observed in Dharani × Bheema (522.22 %), Dharani × ICGV-06188 (128.57 %) and Kadiri-6 × ICGV-95165 (21.35 %). Positive and significant heterosis for number of pods plant^{-1} was recorded in seven crosses, with Dheeraj × ICGV-171377 (26.32 %), Narayani × ICGV-06188 (20.55 %), Dheeraj × ICGV-95165 (20.37 %), Kadiri-6 x ICGV-171377 (18.42 %) and Kadiri-6 x ICGV-95165 (13.33 %) were the five being the best. Likewise, Kadiri-6 × ICGV-95165 (50.54 %), Dheeraj × ICGV-171377 (47.65 %), Narayani × ICGV-171377 (42.25 %) and Narayani x ICGV-06188 (39.09 %) showed high heterosis for number of matured pods plant^{-1}.

For 100 pod weight, Narayani × Bheema (17.80 %), Dharani × ICGV-171377 (13.63 %), Dheeraj × ICGV-171377 (13.60 %), Kadiri-6 x ICGV-171377 (12.09 %) and Narayani x ICGV-06188 (8.97 %) recorded high positive heterosis, similarly, Narayani × Bheema (38.24 %), Narayani × ICGV-06188 (36.59 %), Dharani × ICGV-171377 (31.12 %), Narayani x ICGV-95165 (29.77 %) and Kadiri-6 x ICGV-95165 (26.52 %) were superior for 100 kernel weight. Whereas, positive and significant heterosis for sound mature kernel (%), shelling percent and dry haulm weight plant^{-1} was also observed in several crosses, particularly Dheeraj × ICGV-171377, Narayani × ICGV-06188 and Kadiri-6 × ICGV-95165.

Significant positive mid parent heterosis for pod yield plant^{-1} was observed in ten crosses, among them Dheeraj x ICGV-171377 (27.11 %), Kadiri-6 x ICGV-171377 (25.03 %), Narayani x ICGV-06188 (23.26 %), Kadiri-6 x ICGV-95165 (19.29 %) and Dharani x ICGV-06188 (11.41 %) were identified as the best heterotic combinations. Similarly, Kadiri-6 × ICGV-171377 (49.69 %), Dheeraj × ICGV-171377 (48.18 %), Narayani × ICGV-06188 (46.61 %) and Kadiri-6 x ICGV-

95165 (41.99 %) exhibited high heterosis for kernel yield plant^{-1}. likewise, positive heterosis for harvest index was highest in Narayani × ICGV-95165 (26.01 %) followed by Kadiri-6 × ICGV-171377 (17.59 %). Similar results for yield and yield attributing traits were reported earlier by [15], [12], [17], [13] and [14].

Among the quality traits, Narayani × Bheema recorded desirable negative heterosis for oil content (-7.23 %). In case of protein Eleven crosses exhibited significant positive heterosis over its mid parent in the crosses *viz.,* Kadiri-6 × ICGV-171377 (27.95 %), Dheeraj × ICGV-171377 (25.92 %), Dheeraj × Bheema (23.55 %) and Narayani x ICGV-06188 (18.95 %). Similarly, Kadiri-6 × ICGV-95165 (41.69 %), Kadiri -6 × ICGV-171377 (37.88 %) Dheeraj × ICGV-95165 (25.88 %), Dheeraj x ICGV-06188 (23.88 %) and Narayani x ICGV-06188 (23.36 %) recorded high significant positive heterosis for sucrose content. Earlier reports by [17] and [18] also indicated significant mid parent heterosis for protein and sucrose content in groundnut.

The present study revealed the expression of heterosis for yield through its component traits. Desirable mid-parent heterosis for yield and yield contributing characters was earlier reported by [15} for number of primary branches plant^{-1}, number of secondary branches plant^{-1} and harvest index; [12] for dry haulm weight plant^{-1}, 100 kernel weight and shelling percentage; and [16] for number of pods plant^{-1}, sound mature kernel percentage, pod yield plant^{-1} and kernel yield plant^{-1}. The desirable mid parent heterosis observed in the present study for number of pods plant^{-1}, number of matured pods plant^{-1}, 100 pod weight, pod yield plant^{-1} and kernel yield plant^{-1} was in agreement with the findings of [13] and [14]

Better parent heterosis

The significant magnitude of better parent heterosis recorded for important yield, yield contributing and quality traits in the present investigation suggested the involvement of over-dominant gene effects in the expression of characters. Dheeraj × ICGV-171377 recorded the highest desirable negative better parent heterosis for both days to 50 % flowering and days to maturity (-19.48 % and -4.13 %, respectively) followed by Kadiri-6 × ICGV-95165, Narayani × ICGV-171377, Narayani × ICGV-06188 and Kadiri-6 x ICGV-171377 (-10.39 %). Similar findings for early flowering and maturity were reported by [19], [20], [21] and [14].

Significant positive better parent heterosis for number of primary branches plant^{-1} was observed in Dheeraj × ICGV-95165 (29.85 %), Kadiri-6 × ICGV-06188 (27.94 %) and Narayani × ICGV-95165 (23.88 %), while Dharani × ICGV-06188 (21.21 %) alone recorded desirable heterosis for secondary branches plant^{-1}. Similarly, Dheeraj × ICGV-95165 (18.18 %), Dheeraj × ICGV-171377 (18.03 %) and Narayani × ICGV-06188 (15.79 %) exhibited significant positive better parent heterosis for number of pods plant^{-1}. Whereas, Kadiri-6 × ICGV-95165 (46.73 %), Narayani × ICGV-06188 (32.42 %) and Dheeraj × ICGV-171377 (27.74 %) were identified as superior crosses for number of matured pods plant^{-1}.

For 100 pod weight and 100 kernel weight, the crosses *viz.,* Dheeraj × ICGV-171377 (10.21 %) and Narayani × ICGV-06188 (20.41 %) respectively, exhibited high positive better parent heterosis. Significant positive better parent heterosis for sound mature kernel (%) was observed in Dheeraj × ICGV-171377 (18.34 %), Dharani × ICGV-171377(13.18 %), Dharani × Bheema (13.15 %) and Narayani × ICGV-06188 (8.82 %), while Kadiri-6 × ICGV-171377 (14.81 %), Dheeraj × ICGV-06188 (13.72 %), Dheeraj x ICGV-171377 (11.65 %) and Narayani x ICGV-06188 (11.14 %) were superior for shelling per cent. Likewise, Dheeraj × ICGV-06188 (13.72 %) and Dheeraj x ICGV-171377 (11.65 %) recorded desirable better parent heterosis for dry haulm weight plant^{-1}.

Among yield traits, Kadiri-6 × ICGV-171377 (19.37 %), Narayani × ICGV-06188 (16.98 %), Dheeraj × ICGV-171377 (15.71 %), Kadiri Amaravathi x ICGV-171377 (14.61 %) and Kadiri-6 x ICGV-95165 (12.91 %) recorded high positive better parent heterosis for pod yield plant^{-1}. Similarly, Kadiri-6 × ICGV-171377 (48.46 %), Narayani × ICGV-06188 (45.11 %), Dheeraj × ICGV-171377 (40.05 %) and Kadiri-6 x ICGV-95165 (37.40 %) were identified as superior crosses for kernel yield plant^{-1}. Positive better parent heterosis for harvest index was highest in Narayani x ICGV-95165 (25.23 %), Kadiri-6 x ICGV-171377 (17.46 %), Narayani x ICGV-06188 (14.48 %), Dheeraj x Bheema (9.99 %) and Kadiri-6 x ICGV-95165 (9.22 %). Similar results for yield and yield contributing traits were earlier reported by [20], [22], [23], [13] and [14].

Among the quality traits, Narayani × Bheema (-8.71 %), Kadiri-6 × ICGV-06188 (-7.21 %) and Narayani × ICGV-06188 (-5.45 %) exhibited desirable negative heterosis for oil content. Significant positive better parent heterosis for protein content was recorded in several crosses, particularly in Kadiri-6 × ICGV-171377 (19.93 %), Dharani × Bheema (18.96 %) and Narayani × ICGV-06188 (12.01 %). Likewise, Kadiri-6 × ICGV-171377 (28.43 %) and Kadiri-6 × ICGV-95165 (20.39 %) showed high positive heterosis for sucrose content. Earlier studies by [24], [17], [25] and [18] also reported similar trends for oil, protein and sucrose content indicating the potential of these crosses for developing high quality groundnut varieties through recombination breeding.

Standard heterosis

Standard heterosis is an important criterion in plant breeding for identifying superior hybrids with potential for commercial exploitation based on their performance over the standard check variety. In the present study, negligible standard heterosis was observed for days to 50 % flowering, days to maturity and plant height. Significant positive standard heterosis for number of primary branches plant^{-1} was recorded in Dheeraj × ICGV-95165 (27.94 %), Kadiri-6 × ICGV-06188 (27.94 %) and Narayani × ICGV-95165 (22.06 %), while Dharani × ICGV-06188 (1500 %), Kadiri-6 × ICGV-95165 (980 %) and Dheeraj × ICGV-95165 (780 %) exhibited high heterosis for secondary branches plant^{-1}.

For number of pods plant^{-1} and number of matured pods plant^{-1}, Dheeraj × ICGV-171377 (35.85 %, 73.90 %), Kadiri-6 × ICGV-171377 (27.36 %, 61.96 %), Dharani × ICGV-171377 (28.30 %, 57.61 %) and Narayani × ICGV-06188 (24.53 %, 57.61 %) were identified as superior heterotic combinations. Except Kadiri-6 × ICGV-06188 for 100 pod weight and Kadiri Amaravathi × ICGV-06188 for 100 kernel weight, all the crosses exhibited significant positive standard heterosis over the check variety Kadiri-6. Significant positive standard heterosis for sound mature kernel (%), shelling per cent and dry haulm weight plant^{-1} was predominantly exhibited by Dheeraj × ICGV-171377 and Narayani × ICGV-06188. Other promising crosses such as Kadiri-6 × ICGV-06188, Dheeraj × ICGV-06188 and Narayani × ICGV-171377 also recorded desirable heterotic effects for these traits.

Nine crosses recorded positive significant standard heterosis for pod yield plant^{-1}. The top five combinations were Kadiri-6 x ICGV-171377 (31.26 %), Narayani x ICGV-06188 (30.08 %), Dheeraj x ICGV-171377 (27.23 %), Kadiri-6 x ICGV-95165 (26.44 %) and Dharani x ICGV-06188 (14.32 %). Similarly, among eleven heterotic crosses for kernel yield plant^{-1}, Kadiri-6 x ICGV-171377 (50.95 %), Narayani x ICGV-06188 (50.49 %), Dheeraj x ICGV-171377 (42.40 %), Kadiri-6 x ICGV-95165 (37.40 %) and Dheeraj x ICGV-06188 (25.85 %) were identified as the best five heterotic yielders. Likewise, desirable standard heterosis for harvest index was noted in seven crosses, the top five crosses were Narayani x ICGV-95165 (23.31 %), Kadiri-6 x ICGV-171377 (17.46 %), Dheeraj x Bheema (11.93 %), Narayani x Bheema (10.07 %) and Kadiri-6 x ICGV-95165 (9.22 %).

Similar kind of desirable standard heterosis was also documented by [26] for number of primary branches plant^{-1}, number of secondary branches plant^{-1}, dry haulm weight plant^{-1} and shelling per cent; [20] and [9] for pod yield plant^{-1} and kernel yield plant^{-1} and shelling per cent; [24] and [15] for number of pods plant^{-1}, number of matured pods plant^{-1}, dry haulm weight plant^{-1} and harvest index; [12] for sound mature kernel (%), 100 pod weight and 100 kernel weight; [27] and [13] for number of matured pods plant^{-1}, pod yield plant^{-1} and kernel yield plant^{-1}.

In general, substantial standard heterosis in desirable direction was observed in the present study for quality characters, Oil content registered negative heterosis in a range of -7.21 % and -5.45 % in the crosses Narayani x ICGV-06188 and Kadiri-6 x ICGV-06188, respectively. Whereas, all the crosses registered desirable standard heterosis for protein content except Narayani x ICGV-171377. Five crosses *viz.,* Kadiri-6 x ICGV-95165 (72.16 %), Kadiri-6 x ICGV-171377 (48.83 %), Narayani x ICGV-06188 (45.48 %), Dharani x ICGV-95165 (43.59) and Dharani x ICGV-06188 (40.67 %) were identified as superior heterotic crosses with positive significant standard heterosis for sucrose content. Similar estimates of heterosis for quality characters were earlier documented by [24], [25] for oil content; [10] for oil and protein content; [17] and [18] for oil, protein and sucrose content.

From the above results, the crosses *viz.,* Narayani × ICGV-06188, Kadiri-6 × ICGV-95165, Kadiri-6 × ICGV-171377 and Dheeraj × ICGV-171377 were identified as promising reservoirs as they exhibited superior performance for majority of yield and quality traits. The high magnitude of heterosis observed in these crosses suggested the predominance of dominant and over-dominant and non-additive gene action in the expression of yield and its contributing traits in F_1 s. Hence, these crosses could be effectively utilized in recombination breeding programmes for selection of superior segregants with enhanced hybrid vigour.

Based on *per se* performance, combining ability and heterotic response the four crosses *viz.,* Narayani × ICGV-06188, Kadiri-6 × ICGV-95165, Kadiri-6 × ICGV-171377 and Dheeraj × ICGV-171377 were adjudged as the best cross combinations for enhancing pod yield coupled with desirable quality traits in groundnut. However, the relationship between combining ability and heterosis was not always consistent, as crosses exhibiting high heterosis and desirable specific combining ability effects did not necessarily involve parents with high general combining ability effects. This suggested the involvement of inter-allelic interactions and the importance of non-additive gene action in governing these traits. Nevertheless, most of the superior crosses involved at least one good general combiner, emphasizing the importance of evaluating *per se* performance, combining ability and heterotic response together for the identification of suitable parents and superior cross combinations in groundnut breeding programmes.

Conclusion

The cross, Kadiri-6 x ICGV-171377 was identified as the best heterotic cross for pod and kernel yield plant^{-1}, where the predominance of over dominance effects was observed over standard line Kadiri-6 to the extent of 31.26 % for pod yield plant^{-1} and 50.95 % for kernel yield plant^{-1}, respectively. Similarly, Narayani x ICGV-06188, Kadiri-6 x ICGV-95165 and Kadiri-6 x ICGV-171377 were found as best heterotic crosses for both quality traits and yield.

Table 1. Pedigree and salient features of the parents selected for the hybridization programme

S. No	Genotype	Pedigree	Source/Origin	Salient features
	Lines			
1.	Dharani	VRI 2 X TCPG 6	RARS, Tirupati	Withstands drought up to 35 days dry spell, uniform in maturity, high SMK%, attractive pods and tolerant to low light conditions.
2.	Dheeraj	Narayani X JAL30	RARS, Tirupati	Suitable for cultivation in irrigated situation both in *kharif* and *rabi* seasons, medium bold seeded with attractive kernel colour.
3.	Kadiri Amaravathi	Kadiri-6 X NCAc 2242	ARS, Kadiri	Multiple disease resistant (Rust, ELS, LLS, stem rot, PBND, PSND) and tolerant to insect pests, possesses attractive testa colour.
4.	Narayani	JL-24 x Ah316/S	RARS, Tirupati	Early maturing, Drought and heat tolerant, useful for both oil and confectionery purposes.
5.	Kadiri-6	JL-24 x Ah316/S	ARS, Kadiri	Early Maturing, Suitable for *rabi* and posess attractive testa colour.
	Testers			
1.	ICGV 06188	{(BPI Pn9 x ICGV 95172) x [ICGV 88414 X USA 63) x ICGV 95172]}	ICRISAT, Patancheru	Superior pod and kernel features, higher pod yield, higher seed mass and low oil content prefereed for confectionery purpose.
2.	ICGV 171377	(ICGV 08086 x ICG 6671)	ICRISAT, Patancheru	High yielding variety with high shelling per cent, suitable for confectionery purpose.
3.	ICGV 95165	ICGV 88448 M (M-mutant)	ICRISAT, Patancheru	High yielding, medium bold seeded variety with attractive kernel colour, suitable for confectionery purpose.
4.	Bheema	TAG 24 X TG 19	RARS, Tirupati	Early maturing, bold seeded confectionery variety with high sucrose content, suitable for irrigated situation even in *kharif*.

Table 2 Percentage of mid parent heterosis (MH), better parent heterosis (BH) and standard parent heterosis (SH) for days to 50 % flowering and days to maturity in groundnut

S.No.	Crosses	Days to 50% flowering			Days to maturity		
		MH	BH	SH	MH	BH	SH
1.	Dharani x ICGV 06188	14.71**	5.41	16.42**	1.68	-0.82	6.61**
2.	Dharani x ICGV 171377	6.47*	-3.90	10.45**	1.46	-1.62	7.05**
3.	Dharani x ICGV 95165	15.28**	1.22	23.88**	2.27*	-1.98	9.25**
4.	Dharani x Bheema	11.59**	1.32	14.93**	0.00	-1.67	3.96**
5.	Dheeraj x ICGV 06188	-4.96	-9.46	0.00	-1.46	-2.87*	4.41**
6.	Dheeraj x ICGV 171377	-13.89**	-19.48**	-7.46	-4.13**	-6.07**	2.20
7.	Dheeraj x ICGV 95165	16.78**	6.10	29.85**	0.82	-2.37	8.81**
8.	Dheeraj x Bheema	4.90	-3.22	11.94**	-0.21	-0.83	4.85**
9.	Kadiri Amaravathi x ICGV 06188	9.55**	3.61	28.36**	3.82**	1.98	13.66**
10.	Kadiri Amaravathi x ICGV 171377	2.50	-1.20	22.39**	0.80	-0.40	11.01**
11.	Kadiri Amaravathi x ICGV 95165	3.03	2.41	26.87**	1.19	1.19	12.78**
12.	Kadiri Amaravathi x Bheema	-5.66**	-9.64**	11.94**	-1.83	-4.35**	6.61**
13.	Narayani x ICGV 06188	-2.29	-13.51**	-4.48	-2.76*	-6.15**	0.88
14.	Narayani x ICGV 171377	-2.99	-15.58**	-2.99	-1.69	-5.67**	2.64
15.	Narayani x ICGV 95165	15.11**	-2.44	19.40**	1.25	-3.95**	7.05**
16.	Narayani x Bheema	15.79**	1.32	14.93**	1.93	-0.83	4.85**
17.	Kadiri-6 x ICGV 06188	7.80*	2.70	13.43**	4.03**	0.41	7.93**
18.	Kadiri-6 x ICGV 171377	-4.17	-10.39**	2.99	0.84	-3.24*	5.29**
19.	Kadiri-6 x ICGV 95165	-7.38*	-15.85**	2.99	-0.42	-5.53**	5.29**
20.	Kadiri-6 x Bheema	-3.50	-9.21**	2.99	2.36*	-0.42	5.29**
	S.E.	1.09	1.26	1.26	1.27	1.47	1.47

*Significant at 5 % level; ** Significant at 1 % level

Table 3 Percentage of mid parent heterosis (MH), better parent heterosis (BH) and standard parent heterosis (SH) for plant height (cm), number of primary branches plant^{-1} and number of secondary branches plant^{-1} in groundnut

S.No.	Crosses	Plant height (cm)			Number of primary branches plant^{-1}			Number of secondary branches plant^{-1}		
		MH	BH	SH	MH	BH	SH	MH	BH	SH
1.	Dharani x ICGV 06188	38.84**	37.91**	61.43**	-2.61	-6.67	-17.65	128.57**	21.21**	1500.00**
2.	Dharani x ICGV 171377	14.61	6.41	45.35**	9.65	5.93	-8.09	-11.11	-42.86	60.00
3.	Dharani x ICGV 95165	21.02*	15.09	49.35**	21.31*	10.45	8.82	-9.09	-52.38**	700.00**
4.	Dharani x Bheema	-5.99	-13.23	1.57	8.66	-4.17	1.47	522.22**	460.00	460.00**
5.	Dheeraj x ICGV 06188	42.70**	34.98**	74.79**	27.10*	13.33	-0.00	-25.71**	-60.61**	420.00**
6.	Dheeraj x ICGV 171377	-1.28	-3.85	31.34*	22.64*	10.17	-4.41	55.56	-0.00	180.00**
7.	Dheeraj x ICGV 95165	-9.38	-9.48	17.47	52.63**	29.85**	27.94**	-0.00	-47.62**	780.00**
8.	Dheeraj x Bheema	-2.40	-13.88	11.52	9.24	-9.72	-4.41	100.00	80.00	80.00
9.	Kadiri Amaravathi x ICGV 06188	12.18	8.15	34.56*	17.91*	6.76	16.18	-35.00	-60.61**	420.00**
10.	Kadiri Amaravathi x ICGV 171377	13.19	8.15	47.72**	24.81**	12.16	22.06	14.29	14.29	220.00**
11.	Kadiri Amaravathi x ICGV 95165	-2.10	-4.12	24.42	5.67	0.68	9.56	-14.29*	-50.00**	740.00**
12.	Kadiri Amaravathi x Bheema	50.55**	35.19**	68.20**	6.85	5.41	14.71	-36.84	-57.14*	20.00
13.	Narayani x ICGV 06188	3.59	-1.08	14.24	8.11	0.00	-11.76	-60.00**	-78.79**	180.00*
14.	Narayani x ICGV 171377	6.41	-5.87	28.57*	14.55	6.78	-7.35	33.33	-14.29	140.00*
15.	Narayani x ICGV 95165	-3.73	-12.89	13.04	40.68**	23.88**	22.06*	-36.36	-66.67**	460.00**
16.	Narayani x Bheema	-0.84	-3.68	1.20	-13.82	-26.39**	-22.06*	11.11	0.00	0.00
17.	Kadiri-6 x ICGV 06188	4.79	-2.23	12.90	35.94**	27.94**	27.94**	-32.39**	-63.64**	380.00**
18.	Kadiri-6 x ICGV 171377	1.29	-12.28	19.82	14.96	7.35	7.35	-15.79	-42.86	60.00
19.	Kadiri-6 x ICGV 95165	32.77	17.54	52.53**	0.74	0.00	0.00	21.35**	-35.71**	980.00**
20.	Kadiri-6 x Bheema	10.21	9.68	9.68	-17.14*	-19.44*	-14.71	180.00	180.00	180.00*
	S.E.	2.36	2.73	2.73	0.54	0.63	0.63	0.15	0.18	0.18

*Significant at 5 % level; ** Significant at 1 % level

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Table 4 Percentage of mid parent heterosis (MH), better parent heterosis (BH) and standard parent heterosis (SH) for number of pods plant^{-1}, number of matured plant^{-1}, 100 pod weight (g) and 100 kernel weight (g) in groundnut

S.No.	Crosses	Number of pods plant^{-1}			Number of matured pods plant^{-1}			100 pod weight (g)			100 kernel weight (g)		
		MH	BH	SH	MH	BH	SH	MH	BH	SH	MH	BH	SH
1.	Dharani x ICGV 06188	7.14	0.84	13.21	-2.27	-13.65	2.77	-0.84	-9.81**	13.77**	16.62**	3.43	36.14**
2.	Dharani x ICGV 171377	12.86*	11.48	28.30**	38.59**	15.77*	57.61**	13.63**	5.53*	27.18**	31.12**	14.22**	56.75**
3.	Dharani x ICGV 95165	3.09	-0.81	11.36	0.68	-5.97	-1.09	5.64**	-5.28*	23.38**	23.63**	10.66*	42.66**
4.	Dharani x Bheema	8.99	0.84	13.21	14.11	13.10	3.26	1.01	-4.86*	11.24**	20.31**	8.14	38.11**
5.	Dheeraj x ICGV 06188	-14.69*	-15.09	-15.09*	-10.95	-18.26*	-2.72	1.71	-3.46	21.79**	16.58**	11.39*	46.61**
6.	Dheeraj x ICGV 171377	26.32**	18.03**	35.85**	47.65**	27.74**	73.91**	13.60**	10.21**	32.82**	20.89**	13.26**	55.42**
7.	Dheeraj x ICGV 95165	20.37**	18.18*	22.64**	27.47**	24.00*	30.43**	3.16	-3.54	25.64**	14.44**	10.44*	42.37**
8.	Dheeraj x Bheema	6.18	3.77	3.77	16.84	11.09	10.49	3.79	2.19	19.49**	4.11	0.92	28.89**
9.	Kadiri Amaravathi x ICGV 06188	10.13	4.07	15.85*	-11.03	-17.12	-1.36	-3.35	-6.10**	18.46**	-23.24**	-24.03**	0.00
10.	Kadiri Amaravathi x ICGV 171377	7.00	5.25	21.13**	-8.08	-19.36*	9.78	3.85	-4.47	15.13**	-1.01	-4.01	31.72**
11.	Kadiri Amaravathi x ICGV 95165	2.11	-1.36	9.81	-6.16	-7.26	-2.45	-4.98*	-9.09**	18.41**	5.61	5.61	36.14**
12.	Kadiri Amaravathi x Bheema	2.55	-4.75	6.04	4.24	-2.38	0.27	-2.17	-3.02	15.38**	6.92	6.42	37.19**
13.	Narayani x ICGV 06188	20.55**	15.79*	24.53**	39.09**	32.42**	57.61**	8.97**	-1.63	24.10**	36.59**	20.41**	58.49**
14.	Narayani x ICGV 171377	11.86*	8.20	24.53**	42.25**	27.35**	73.37**	7.58**	-0.85	19.49**	3.09	-10.73*	22.51**
15.	Narayani x ICGV 95165	10.71	8.77	16.98*	21.06*	19.70*	28.80**	5.27*	-6.30**	22.05**	29.77**	15.44**	48.82**
16.	Narayani x Bheema	10.78	4.56	12.45	20.94*	10.86	19.29	17.80**	10.09**	28.72**	38.24**	23.48**	57.70**
17.	Kadiri-6 x ICGV 06188	11.09	10.57	10.57	17.62*	8.22	28.80**	-10.20**	-19.51**	1.54	9.42*	-3.73	26.72**
18.	Kadiri-6 x ICGV 171377	18.42**	10.66	27.36**	37.17**	18.96*	61.96**	12.09**	2.55	23.59**	23.51**	6.76	46.51**
19.	Kadiri-6 x ICGV 95165	13.33*	11.27	15.47*	50.54**	46.73**	54.53**	7.80**	-4.72*	24.10**	26.52**	12.33**	44.81**
20.	Kadiri-6 x Bheema	10.04	7.55	7.55	10.60	4.89	4.89	6.86**	-0.88	15.90**	-0.22	-11.05*	13.60*
	S.E.	1.58	1.82	1.82	1.62	1.87	1.87	2.24	2.59	2.59	1.97	2.27	2.27

*Significant at 5 % level; ** Significant at 1 % level

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Table 5 Percentage of mid parent heterosis (MH), better parent heterosis (BH) and standard parent heterosis (SH) for sound mature kernel (%), shelling per cent (%) and dry haulm weight plant^{-1} (g) in groundnut

S.No.	Crosses	Sound mature kernel (%)			Shelling per cent (%)			Dry haulm weight plant^{-1} (g)		
		MH	BH	SH	MH	BH	SH	MH	BH	SH
1.	Dharani x ICGV 06188	4.07	2.22	-1.37	0.92	-4.60	-2.33	-0.16	-7.82	2.22
2.	Dharani x ICGV 171377	14.02**	13.18**	9.20*	16.45**	10.70*	13.34*	3.86	-4.02	6.22
3.	Dharani x ICGV 95165	-29.06**	-30.83**	-33.26**	-4.36	-13.22*	-11.15*	-19.79*	-27.62**	-15.56
4.	Dharani x Bheema	15.90**	13.15**	9.17*	6.02	4.38	6.87	-1.05	-2.25	-8.22
5.	Dheeraj x ICGV 06188	8.94*	6.16	4.10	18.99**	13.72*	13.78*	37.85**	28.46**	42.44**
6.	Dheeraj x ICGV 171377	20.18**	18.34**	16.05**	16.16**	11.65*	11.70	33.69**	24.70**	38.00**
7.	Dheeraj x ICGV 95165	-8.53*	-11.51**	-13.22	-4.81	-12.73*	-12.68*	3.56	-5.71	10.00
8.	Dheeraj x Bheema	7.21	3.84	1.83	-4.15	-4.56	-4.51	-22.68*	-24.36*	-27.56**
9.	Kadiri Amaravathi x ICGV 06188	-9.41*	-11.25**	-13.92**	-8.41	-12.96*	-11.88*	-19.86**	-21.77**	-8.91
10.	Kadiri Amaravathi x ICGV 171377	-3.60	-4.55	-7.43	-13.78**	-17.60**	-16.57**	-13.50	-15.65	-1.78
11.	Kadiri Amaravathi x ICGV 95165	-1.48	-4.18	-7.06	-5.33	-13.67*	-12.60*	-0.86	-0.95	15.56
12.	Kadiri Amaravathi x Bheema	5.45	2.69	-0.40	-11.05*	-11.94*	-10.85*	-8.17	-17.96*	-4.47
13.	Narayani x ICGV 06188	13.18**	8.82*	9.71*	18.36**	11.14*	15.43**	-19.13*	-20.52*	-11.87
14.	Narayani x ICGV 171377	10.31**	7.16	8.04*	10.81*	4.63	8.67	16.76*	14.86	27.11**
15.	Narayani x ICGV 95165	-4.05	-8.41*	-7.66	-0.89	-10.65*	-7.20	-44.99**	-47.26**	-38.47**
16.	Narayani x Bheema	-3.24	-7.52	-6.76	-7.05	-9.14	-5.63	-17.91*	-23.83**	-18.44
17.	Kadiri-6 x ICGV 06188	10.05**	6.22	6.22	5.78	1.12	1.12	14.44	8.82	20.67*
18.	Kadiri-6 x ICGV 171377	3.19	0.64	0.64	19.41**	14.81**	14.81**	-21.94**	-25.70**	-17.78
19.	Kadiri-6 x ICGV 95165	11.93**	7.27	7.27	18.33**	8.51	8.51	-7.69	-14.29	0.00
20.	Kadiri-6 x Bheema	5.69	1.42	1.42	0.51	0.11	0.11	-9.78	-13.56	-13.56
	S.E.	2.61	3.01	3.01	2.97	3.43	3.43	1.76	2.04	2.04

*Significant at 5 % level; ** Significant at 1 % level

Table 6 Percentage of mid parent heterosis (MH), better parent heterosis (BH) and standard parent heterosis (SH) for pod yield plant^{-1} (g), kernel yield plant^{-1} (g) and harvest index (%) in groundnut

S. No	Crosses	Pod yield plant^{-1} (g)			Kernel yield plant^{-1} (g)			Harvest index (%)		
		MH	BH	SH	MH	BH	SH	MH	BH	SH
1.	Dharani x ICGV 06188	11.41**	2.81	14.32**	12.65**	9.83*	11.58*	4.61	4.29	4.43
2.	Dharani x ICGV 171377	8.55*	0.69	10.72**	26.84**	23.62**	25.69**	2.28	2.15	1.91
3.	Dharani x ICGV 95165	-0.43	-8.41*	2.57	-3.95	-5.42	-8.72	8.68**	8.10*	7.58*
4.	Dharani x Bheema	8.93*	7.94	3.37	15.42**	14.62**	10.62*	4.09	2.94	4.76
5.	Dheeraj x ICGV 06188	9.60**	-0.74	10.38*	31.02**	23.87**	25.85**	-9.39**	-10.42**	-10.29**
6.	Dheeraj x ICGV 171377	27.11**	15.71**	27.23**	48.18**	40.05**	42.40**	-2.07	-3.00	-3.22
7.	Dheeraj x ICGV 95165	5.85	-4.43	7.02	1.74	0.09	-6.37	0.82	0.51	-1.03
8.	Dheeraj x Bheema	6.44	3.37	-1.01	2.00	-0.50	-5.30	12.14**	9.99*	11.93**
9.	Kadiri Amaravathi x ICGV 06188	-11.26**	-14.78**	-5.24	-18.54**	-19.41**	-16.34**	4.15	1.43	1.57
10.	Kadiri Amaravathi x ICGV 171377	-11.55**	14.61**	-6.10	-23.67**	-24.45**	-21.57**	0.99	-1.47	-1.70
11.	Kadiri Amaravathi x ICGV 95165	-12.59**	-16.35**	-6.32	-16.83**	-20.95**	-17.93**	-5.33	-7.04*	-8.47*
12.	Kadiri Amaravathi x Bheema	-11.17**	-14.04**	-12.00**	-21.09**	-24.37**	-21.48**	-1.66	-4.97	-3.29
13.	Narayani x ICGV 06188	23.26**	16.98**	30.08**	46.61**	45.11**	50.49**	16.16	14.48**	14.64**
14.	Narayani x ICGV 171377	-1.94	-6.44	2.88	9.06*	7.99	12.00*	-7.06	-8.23*	-8.44*
15.	Narayani x ICGV 95165	11.23**	5.22	17.83**	10.77**	5.34	9.25*	26.01**	25.23**	23.31**
16.	Narayani x Bheema	8.19*	5.96	5.83	0.45	-3.68	-0.11	10.61**	8.16*	10.07**
17.	Kadiri-6 x ICGV 06188	5.91	0.58	11.84**	12.11**	11.23*	13.00**	-3.11	-3.18	-3.04
18.	Kadiri-6 x ICGV 171377	25.03**	19.37**	31.26**	49.69**	48.46**	50.95**	17.59**	17.46**	17.46**
19.	Kadiri-6 x ICGV 95165	19.29**	12.91**	26.44**	41.99**	37.40**	37.40**	10.07**	9.22**	9.22**
20.	Kadiri-6 x Bheema	4.86	2.64	2.64	5.49	2.94	2.94	5.79	4.88	6.73
	S.E.	1.15	1.33	1.33	0.88	1.01	1.01	1.74	2.01	2.01

*Significant at 5 % level; ** Significant at 1 % level

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Table 7 Percentage of mid parent heterosis (MH), better parent heterosis (BH) and standard parent heterosis (SH) for oil content (%), protein content (%) and sucrose content (%) in groundnut

S.No.	Crosses	Oil content (%)			Protein content (%)			Sucrose content (%)		
		MH	BH	SH	MH	BH	SH	MH	BH	SH
1.	Dharani x ICGV 06188	2.20	-1.89	0.11	3.95	-0.18	13.92**	23.88*	-0.92	40.67**
2.	Dharani x ICGV 171377	3.98	1.90	3.98	25.52**	20.42	37.70**	-24.29*	-34.34**	-23.91
3.	Dharani x ICGV 95165	3.58	0.99	3.05	17.75**	12.18	30.17**	25.88**	0.41	43.59**
4.	Dharani x Bheema	2.04	0.00	2.04	23.55**	18.96**	35.02**	-35.47**	-49.57**	-23.76
5.	Dheeraj x ICGV 06188	3.10	-1.02	1.00	13.31**	7.02*	22.15**	-26.68**	-38.50**	-12.68
6.	Dheeraj x ICGV 171377	5.10*	3.00	5.10	5.57	-0.37	13.92**	-18.90	-25.79*	-13.99
7.	Dheeraj x ICGV 95165	-4.62	-7.00	-5.10	1.07	-5.27	9.92**	-38.82**	-48.83**	-26.82*
8.	Dheeraj x Bheema	2.04	0.00	2.04	11.29**	5.39	19.62**	-44.37**	-54.48**	-31.20*
9.	Kadiri Amaravathi x ICGV 06188	5.15*	0.00	4.08	3.73	2.68	17.19**	-36.15**	-55.03**	-36.15**
10.	Kadiri Amaravathi x ICGV 171377	7.07**	3.92	8.16	9.51**	8.30**	23.84**	-43.84**	-57.86**	-51.17**
11.	Kadiri Amaravathi x ICGV 95165	3.55	0.00	4.08	1.85	0.00	16.03**	-19.36	-43.32**	-18.95
12.	Kadiri Amaravathi x Bheema	1.01	-1.96	2.04	-0.75	-1.49	11.81**	-28.92**	-50.82**	-25.66*
13.	Narayani x ICGV 06188	-2.46	-5.45*	-5.45*	18.95**	12.01**	27.85**	23.36*	2.46	45.48**
14.	Narayani x ICGV 171377	4.12	3.06	3.66	-2.60	-8.36**	4.79	-14.52	-22.64*	-10.35
15.	Narayani x ICGV 95165	1.55	0.00	0.00	3.12	-3.64	11.81**	-43.88**	-53.52**	-33.53*
16.	Narayani x Bheema	-7.23**	-8.17**	-8.17	4.34	-1.49	11.81**	-8.74	-26.04**	11.81
17.	Kadiri-6 x ICGV 06188	-4.28	-7.21**	-7.21**	15.09**	7.97*	23.23**	-5.66	-19.61*	14.114
18.	Kadiri-6 x ICGV 171377	-4.04	-5.02	-5.02	27.95**	19.93**	37.13**	37.88**	28.43*	48.83**
19.	Kadiri-6 x ICGV 95165	0.54	-1.00	-1.00	11.72**	4.00	20.68**	41.69**	20.39*	72.16**
20.	Kadiri-6 x Bheema	3.71	2.65	-2.65	14.17**	7.38*	21.88**	-10.39	-25.55**	12.54
	S.E.	1.08	1.24	1.24	0.70	0.81	0.81	0.37	0.42	0.42

*Significant at 5 % level; ** Significant at 1 % level

Plate 1 Field view of hybridization block during *kharif*, 2020

Plate 2 Field view of evaluation of F_1 generation along with parents during *rabi*, 2020

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