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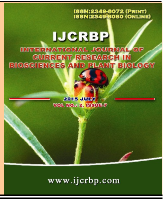

Original Research Article

Heterosis and Inbreeding Depression for Yield and Yield Attributes in Groundnut (*Arachis hypogaea* L.)

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Abstract

A study was conducted in groundnut assess the extent of the heterosis for twelve quantitative traits including pod and kernel yields per plant. Among the parents TPT-4 recorded the better *per se* performance for number of well-filled and mature pods per plant, shelling per cent, SMK per cent, 100-kernel weight, kernel yield per plant and pod yield per plant. The parent, ICGV-91114 came to maturity early. Among the F_1s, TPT-4 × TIR-25 for number of well-filled and mature pods per plant, shelling per cent, kernel yield per plant and pod yield per plant exhibited the highest per se performance. In F_2 generation, TPT-4 × ICGV-91114 was distinct for its lowest mean value for days to maturity and highest mean values for number of well-filled and mature pods per plant, shelling per cent, 100- kernel weight. The F_2 involving JL-220 as one of the parents *viz*., JL-220 × TCGS-647 for SMK per cent, protein per cent, kernel yield per plant and pod yield per plant showed the highest *per se* performance. TPT-4 × TIR-25 had recorded significant standard heterosis for kernel yield per plant. Therefore, for exploitation of such heterosis in future breeding programmes either recurrent selection or diallel selective mating system is to be examined in these crosses. Further, the crosses which recorded high heterosis for pod yield also recorded high inbreeding depression in F_2 generation indicating importance of non-additive gene action.

Keywords

Groundnut
Heterosis
Inbreeding depression
Yield attributes

Introduction

Most of the groundnut breeding programmes aimed at improving productivity have been directed towards hybridization followed by selection in segregating generation. Since groundnut is a predominately self pollinated crop and commercial product of F_1 seed is not currently feasible, it was felt that heterosis in groundnut is unstable. However, the magnitude of heterosis provide the basis of genetic diversity and a guide for choice of desirable parents for developing superior F_1 hybrids to exploit hybrid vigour and are building gene pool to be employed in breeding programme. Heterosis in F_1 generation expressed in terms of superiority over the better / mid-parent/standard parent is of direct relevance not only for developing hybrids in cross-pollinated crops, but also in self pollinated crops because heterotic crosses help the breeder to select appropriate crosses which would lead to desirable transgressive segregants in advanced generations (Arunachalam et al., 1984). Stokes and Hull (1930) first observed the manifestation of heterosis for different traits in groundnut. Since then, several investigators reported heterosis for yield and its components in groundnut (Deshmukh et al., 1985 and Dwivedi et al., 1994). According to the available evidence, heterosis in groundnut is related to the parental genetic diversity. Promising F1s with desirable traits may be advanced further to obtained transgressive segregants. Therefore with present study, the magnitude of heterosis and inbreeding depression for pod yield and other physiology traits were studied in 28 groundnut crosses in F_1 and F_2 generations.

Materials and methods

The experimental material comprised of 28 F_1 and F_2 crosses of a half diallel desired of eight parental genotypes *viz.*, TPT-4, TIR-25, ICGV-91114, TCGS-584, JL-220, ICGV-99029, K-1375 and TCGS-647. These were grown in a randomized block design with three replications during *rabi* 2009 at RARS, Tirupati. The F_1 hybrids were grown in plots consisting of single row of 5m length having a spacing of 22.5×10cm. The parental genotype F_2 crosses had three rows, each of 4m length. In parents and F_1 hybrids, twenty plants per replication per genotype and in F_2 crosses 30 plants per replication per cross were sampled for recording observation.

Data were recorded on fourteen characters, *viz.*, days to 50% flowering, days to maturity, for number of well filled and mature pods per plant, shelling per cent, sound mature kernel per cent, 100 kernel weight (gram per plant), dry haulms yield per plant (gram per plant), harvest index (%), oil per cent, protein per cent, kernel yield per plant (gram per plant) and pod yield per plant (gram per plant). Heterosis over mid parent (>MP) better parent (>BP) and standard parent (>SP) in F_1 generation and in breeding depression from F_1 to F_2 in each cross were estimated for fourteen characters using standard formulae.

Results and discussion

Mean performance of parents, F_1s and F_2s

The mean performance of parents, F_1s and F_2 populations are presented in Table 1. The mean for days to 50 per cent flowering among parents ranged from 27.00 days (ICGV-91114) to 33.00 days (ICGV-99029) with a general mean of 30.00 days. Four parental lines viz., Tirupati-4, ICGV-91114, TCGS-584 and JL-220 recorded low mean for days to 50 per cent flowering than general mean (30.00). The overall mean of days to 50% flowering among F_1s was 26.33. The range for days to 50% flowering among F_1 s ranged from 24.00 (ICGV-91114 × TCGS-647) to 32.00 days (ICGV-99029 × K-1375). Days to 50% flowering among F_2 populations was ranged from 23.00 days (ICGV-91114 × JL-220) to 31.00 days (ICGV-99029 × K-1375) with a general mean of 26.00 days. The range for days to maturity among the parents varied from 100 (ICGV-91114) to 116 days (ICGV-99029) with a general mean of 107.92 days. The earliest maturity was recorded by ICGV-91114 (100 days). The mean of F_1s was 106.86 days with a range of 100.00 (TPT- 4 × ICGV-91114) to 114.00 days (ICGV-99029 × TCGS-647). In F_2 populations, mean days to maturity ranged from 99.00 (TPT-4 × ICGV-91114) to 123.00 (K-1375 × TCGS- 647) with a general mean of 107.00 days. The F_2 population mean of 15 crosses not exceeded the general mean (107.00 days).

Among parents, ICGV-99029 recorded the lowest mean number of well-filled and mature pods per plant (13.70) while it was highest (28.10) in TPT-4, the general mean being 20.28. Five parents had higher mean number of pods than parental mean. The mean number of mature pods per plant ranged from 14.07 (ICGV-91114 × ICGV-99029) to 29.93 (TPT-4 × TIR-25) among F_1s. The general mean of 18.50 was exceeded by twelve F_1s. It ranged from 10.90 to 24.21 in F_2 generation of 28 crosses. The F_2 populations, TPT-4 × ICGV-91114 exhibited the highest mean number of mature pods per plant (24.21), while TPT-4 × Jl-220 had the least mean number of mature pods per plant (10.90). Eleven F_2 populations recorded more mean number of pods per plant than general mean (14.38).

The range of variation for shelling per cent was between 71.58% and 81.39% with a general mean of 77.58%. The genotype, TCGS-647 registered the lower shelling percent of 77.74%, while maximum shelling per cent was recorded by TPT-4. Five parents exhibited more shelling per cent than general mean of parents. Mean shelling percent ranged from 74.22% (ICGV-91114 × TCGS-584) to 81.72% (TPT-4 × TIR-25) among F_1s with general of 78.55%. Fifteen F_1s had higher mean shelling per cent than general mean of F_1s. Among F_2 populations, ICGV-99029 × TCGS-647 recorded the lowest (69.05%) and highest (88.77%) shelling per cent, respectively. Fourteen F_2 populations had higher shelling per cent than general mean (77.30%).

Table 1. ***Per se*** **performance of parents, F_1s and F_2s for yield and yield traits in groundnut.**

Parents/crosses	Days to 50% flowering		Days to maturity		No. of well filled and mature pods per plant		Shelling per cent		Sound mature kernel per cent		100-kernel weight	
	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
Parents												
TPT-4	28.00	-	105.33	-	28.10	-	81.39	-	90.81	-	53.46	
TIR-25	31.00	-	110.00	-	23.20	-	79.49	-	88.73	-	43.12	-
ICGV-91114	26.67	-	100.00	-	24.33	-	78.60	-	87.62	-	47.17	-
TCGS-584	27.67	-	102.33	-	14.27	-	78.66	-	87.82	-	38.46	-
JL-220	27.33	-	105.33	-	20.90	-	77.00	-	88.27	-	51.13	-
ICGV-99029	33.33	-	116.00	-	13.70	-	74.51	-	85.64	-	48.32	-
K-1375	31.00	-	111.00	-	24.00	-	79.43	-	83.42	-	44.05	-
TCGS-647	32.00	-	113.33	-	13.77	-	71.58	-	77.74	-	46.45	-
Crosses												
TPT-4 × TPT-25	24.67	24.00	105.00	104.33	29.93	16.50	81.72	80.07	90.94	87.54	46.26	47.80
TPT-4 × ICGV-91114	24.00	23.67	100.00	99.33	29.03	24.21	81.62	80.77	87.94	87.80	50.68	51.83
TPT-4 × TCGS-584	25.00	24.33	101.33	102.00	22.67	13.30	77.22	77.54	93.56	88.86	50.90	44.94
TPT-4 × JL-220	24.00	24.67	103.67	103.67	16.50	10.90	81.13	76.22	82.69	85.77	50.26	46.22
TPT-4 × ICGV-99029	26.00	23.67	108.67	108.33	15.43	13.60	79.35	74.18	88.81	87.47	49.72	47.35
TPT-4 × K-1375	25.67	25.67	109.00	108.33	27.00	12.42	81.38	77.09	89.11	88.03	49.83	45.41
TPT-4 × TCGS-647	26.00	26.33	112.33	112.00	16.00	14.17	79.73	78.44	89.89	87.88	49.10	55.50
TIR-25 × ICGV-91114	26.67	25.67	102.33	103.00	14.90	16.17	80.72	80.30	84.74	88.75	47.13	46.53
TIR-25 × TCGS-584	27.00	26.33	102.67	104.00	15.37	12.45	77.84	77.89	88.04	86.31	46.97	39.66
TIR-25 × JL-220	27.00	25.67	101.33	106.00	15.57	17.14	76.87	79.37	86.47	91.65	43.64	46.10
TIR-25 × ICGV-99029	26.33	26.00	113.00	113.00	22.60	14.43	74.37	78.99	88.01	85.28	49.90	46.97
TIR-25 × K-1375	26.67	25.67	109.67	108.67	19.97	16.09	77.75	78.01	89.74	90.31	47.42	46.76
TIR-25 × TCGS-647	26.33	27.00	109.67	110.00	15.87	14.42	77.36	79.13	85.08	80.00	37.83	47.83
ICGV-91114 × TCGS-584	25.67	25.00	101.00	100.00	15.67	13.95	74.22	76.12	90.05	83.01	47.75	45.23
ICGV-91114 × JL-220	25.67	25.33	102.33	102.67	15.47	15.39	81.02	76.57	89.69	90.08	45.52	46.61
ICGV-91114 × ICGV-99029	25.33	26.67	106.00	101.67	14.07	13.70	80.68	76.20	88.79	88.59	48.53	47.42
ICGV-91114 × K-1375	25.33	23.33	104.33	102.00	20.17	14.10	76.05	80.38	86.90	90.73	48.39	51.13
ICGV-91114 × TCGS-647	23.67	25.67	108.00	106.33	25.70	11.05	78.54	77.29	91.81	87.46	48.70	45.31
TCGS-584 × JL-220	25.00	24.67	105.00	103.67	15.50	14.70	80.00	73.67	89.33	86.34	49.08	40.18
TCGS-584 × ICGV-99029	26.67	27.00	109.33	109.67	14.73	18.15	74.62	70.97	82.16	85.16	44.60	43.62
TCGS-584 × K-1375	25.00	25.67	109.67	110.67	15.93	15.60	76.07	78.40	88.82	85.16	55.84	45.40
TCGS-584 × TCGS-647	25.33	25.33	109.00	109.00	20.67	11.42	78.59	73.28	87.41	86.62	43.32	42.34
JL-220 × ICGV-99029	26.00	26.67	108.00	106.67	14.53	11.48	78.69	79.79	89.55	93.41	48.09	48.09
JL-220 × K-1375	27.67	26.67	105.33	106.33	14.40	12.41	77.56	80.25	87.00	89.37	46.15	47.78
JL-220 × TCGS-647	27.67	27.67	107.67	111.67	22.17	13.03	79.17	79.76	93.31	91.33	48.82	47.90
ICGV-99029 × K-1375	32.00	31.33	112.00	114.33	15.13	14.92	79.34	75.09	81.67	80.87	45.35	47.69
ICGV-99029 × TCGS-647	31.67	30.00	113.67	114.67	18.60	14.16	77.45	69.05	89.15	87.75	46.39	45.52
K-1375 × TCGS-647	29.33	30.33	112.00	123.00	14.40	12.85	80.21	79.58	87.31	88.26	50.00	48.28
Mean of parents	29.63	-	107.92	-	20.28	-	77.58	-	86.26	-	46.52	-
Range among parents	26.67-33.30	-	100.00-116.00	-	13.70-28.10	-	71.58-81.39	-	77.74 – 90.81	-	38.46-53.46	-
Mean of F_1s	26.33	-	106.86	-	18.50	-	78.55	-	88.14	-	47.72	-
Range among F_1s	23.67-32.00	-	100.00-113.67	-	14.07-29.93	-	74.22-81.72	-	81.67-93.56	-	37.83-55.4	-
Mean of F_2s	-	26.07	-	107.32	-	14.38	-	77.30	-	87.49	-	46.62
Range among F_2s	-	23.33-31.33	-	99.33-123.00	-	10.90-24.21	-	69.05-80.77	-	80.00-93.41	-	39.66-55.50
CD at 5% level	1.31	1.27	1.84	6.36	4.66	3.35	4.91	7.32	6.65	6.42	7.40	5.97

Contd…

Table 1 Contd…

Parents/crosses	Dry haulms yield per plant		Harvest index		Oil per cent		Protein per cent		Kernel yield per plant		Pod yield per plant	
	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
Parents												
TPT-4	12.23	-	33.93	-	48.03	-	26.20	-	18.36	-	22.63	-
TIR-25	14.23	-	39.02	-	48.31	-	26.17	-	15.80	-	19.77	-
ICGV-91114	13.57	-	38.56	-	47.68	-	26.17	-	16.97	-	21.59	-
TCGS-584	11.73	-	40.29	-	47.90	-	26.27	-	12.90	-	16.37	-
JL-220	13.33	-	37.12	-	47.96	-	26.30	-	14.94	-	18.64	-
ICGV-99029	19.23	-	50.25	-	47.93	-	26.13	-	15.45	-	19.31	-
K-1375	15.47	-	45.94	-	47.83	-	25.73	-	13.17	-	17.89	-
TCGS-647	17.97	-	49.09	-	46.83	-	26.30	-	12.87	-	17.99	-
Crosses												
TPT-4 × TPT-25	17.47	14.04	36.49	35.92	47.93	47.77	26.07	26.30	22.60	18.78	27.67	23.68
TPT-4 × ICGV-91114	16.63	18.11	44.90	44.80	47.83	47.80	26.53	26.63	17.57	18.38	21.61	22.09
TPT-4 × TCGS-584	11.37	16.48	28.22	47.68	47.37	47.80	26.50	26.40	20.82	12.98	25.62	16.57
TPT-4 × JL-220	13.40	9.61	38.99	33.41	47.53	47.77	26.50	26.57	19.36	14.07	23.85	18.30
TPT-4 × ICGV-99029	12.50	14.48	34.70	45.27	47.33	47.30	26.50	26.70	19.29	13.28	24.35	17.76
TPT-4 × K-1375	15.40	12.06	38.35	40.01	47.50	47.90	26.53	26.10	18.21	14.64	25.91	18.95
TPT-4 × TCGS-647	18.20	13.91	40.19	36.56	47.70	46.97	26.60	26.57	19.20	16.83	24.13	21.55
TIR-25 × ICGV-91114	12.13	14.62	39.58	42.42	48.10	48.40	26.33	26.47	14.57	16.16	17.97	20.07
TIR-25 × TCGS-584	16.67	13.27	44.26	46.85	48.17	48.10	26.30	26.47	15.67	14.05	20.00	17.68
TIR-25 × JL-220	21.07	13.35	48.62	34.64	48.47	48.10	26.17	26.40	16.13	17.25	20.76	21.88
TIR-25 × ICGV-99029	17.37	15.83	43.67	40.77	47.70	47.70	26.43	26.37	18.28	16.86	24.71	21.17
TIR-25 × K-1375	13.27	13.21	40.09	43.28	48.10	48.37	26.30	26.23	17.11	16.95	22.10	21.67
TIR-25 × TCGS-647	19.37	16.06	46.14	46.13	47.87	47.87	26.23	26.10	16.63	17.77	21.34	21.48
ICGV-91114 × TCGS-584	16.27	11.53	40.85	42.66	47.63	47.87	26.30	26.03	15.80	10.78	21.13	14.11
ICGV-91114 × JL-220	15.77	9.99	42.84	28.88	47.73	47.50	26.30	26.63	19.03	16.58	23.71	21.71
ICGV-91114 × ICGV-99029	26.47	17.11	55.77	46.96	47.50	47.33	26.57	26.60	19.37	16.61	23.84	21.94
ICGV-91114 × K-1375	19.47	15.22	44.12	46.24	46.40	47.53	26.37	26.60	20.07	13.54	25.98	16.97
ICGV-91114 × TCGS-647	15.50	14.92	38.44	39.27	47.37	47.40	26.60	26.73	20.97	13.76	25.80	20.15
TCGS-584 × JL-220	11.13	12.90	33.98	40.23	47.97	48.07	26.37	26.53	16.02	13.99	19.67	19.12
TCGS-584 × ICGV-99029	17.07	27.91	43.93	63.09	47.67	47.47	26.57	26.50	15.14	14.38	19.75	19.81
TCGS-584 × K-1375	20.57	17.88	43.00	52.04	47.90	47.47	26.40	26.40	19.22	13.42	25.50	17.05
TCGS-584 × TCGS-647	15.03	12.97	46.73	44.45	47.63	46.97	26.57	26.40	14.40	11.67	20.96	15.86
JL-220 × ICGV-99029	12.40	15.82	34.63	45.22	47.60	47.83	26.30	26.50	15.57	16.55	19.83	20.93
JL-220 × K-1375	11.87	10.36	34.93	32.64	47.83	48.13	26.60	26.47	16.43	15.15	21.37	18.97
JL-220 × TCGS-647	19.47	12.94	46.00	32.62	47.80	46.93	26.67	26.73	15.37	20.45	19.50	25.59
ICGV-99029 × K-1375	16.97	15.80	42.56	44.33	46.97	47.20	26.37	26.57	19.59	16.98	24.49	22.37
ICGV-99029 × TCGS-647	30.23	19.65	53.73	53.60	46.37	47.40	26.10	26.53	16.49	13.87	21.40	19.65
K-1375 × TCGS-647	26.07	23.41	48.87	57.02	47.77	46.80	26.37	26.20	20.52	11.82	24.60	20.46
Mean of parents	14.72	-	41.78	-	47.77	-	26.16	-	15.06	-	19.27	-
Range among parents	11.73-19.23	-	33.93-50.25	-	46.83-48.31	-	25.73-26.30	-	12.87-18.36	-	16.37-22.63	-
Mean of F_1s	17.11	-	41.95	-	47.63	-	26.41	-	17.84	-	22.77	-
Range among F_1s	11.13-30.23	-	28.22-55.77	-	46.37-48.47	-	26.07-26.67	-	14.40-22.60	-	17.97-27.67	-
Mean of F_2s	-	15.12	-	43.11	-	47.63	-	26.45	-	15.27	-	19.91
Range among F_2s	-	9.61-23.41	-	28.88 – 63.09	-	46.80-48.40	-	26.03-26.73	-	10.78-20.45	-	14.11-25.59
CD at 5% level	6.80	5.34	10.30	11.73	0.64	0.65	0.46	0.51	3.82	5.00	5.11	5.07

The mean SMK per cent among parents ranged between 77.74% (TCGS-647) and 90.81% (TPT-4) with a general mean of 86.26%. Five parental genotypes exceeded the general parental mean. Among the F_1s, IVGV-99029 × K-1375 recorded the lowest (81.67%) and highest (93.56%) SMK per cent was recorded by TPT-4 × TCGS-584 respectively. Fifteen F_1s have shown higher mean SMK per cent than F_1s general mean (88.14%). Among F_2 populations, TIR-25 × TCGS-647 had the lowest (80.00%) and the highest SMK per cent (93.41%) respectively, with a general mean of 87.49%. Sixteen F_2 populations registered high mean SMK per cent than general mean of F_2s.

Among parents, TCGS-584 recorded the lowest mean 100-kernel weight (38.46g) while it was highest (53.46g) in TPT-4, the general mean being 46.52. Four parents had higher mean 100-kernel weight than parental mean. The mean 100-kernel weight ranged from 37.83g (TIR-25 × TCGS-647) to 55.84g (TCGS-584 × K-1375) among F_1s. The general mean of 47.72g was exceeded by sixteen F_1s. It ranged from 39.66g to 55.50g in F_2 generation of 28 crosses. The F_2 populations, TPT-4 × TCGS-647 exhibited the highest mean 100-kernel weight (55.50g), while TIR-25 × TCGS-584 had the least mean 100-kernel weight (39.66g). Thirteen F_2 populations recorded more mean 100-kernel weight than general mean (46.62g).

Mean dry haulm weight per plant ranged from 11.73g to 19.23g among parents. The genotype, ICGV-99029 recorded the highest dry haulm weight per plant of 19.23g while, TCGS-584 had lowest dry haulm weight per plant of 11.73g. Three parents recorded more dry haulm weight per plant than parental general mean. A wide range of 11.13g (TCGS-584 × JL-220) to 30.23g (ICGV-99029 × TCGS-647) was observed among F_1s with a general mean of 17.11g. Eleven out of 28 F_1s registered higher dry haulm weight per plant than general mean of F_1s. Among 28 F_2 population, the mean dry haulm weight per plant was minimum (9.61g) in TPT-4 × JL-220 while it was maximum (23.41g) in K-1375 × TCGS-647. Twelve F_2 populations showed more dry haulm weight per plant than the general mean of 15.12g.

The parental genotype, TPT-4 (33.93%) recorded the lowest and ICGV-99029 the highest harvest index (50.25%) with the general mean of 41.78%. Three parents had higher harvest index than parental mean. Harvest index ranged from 28.22% to 55.77% among the F_1s with a general mean of 41.95%, which was surpassed by fifteen F_1s. The F_1, ICGV-91114 × ICGV-99029 had the highest harvest index (55.77%) and it was lowest (28.22%) in TPT-4 × TCGS-584. Harvest index ranged from 28.88% to 63.09% with a overall mean of 43.11% in F_2 generation. Fifteen F_2 populations mean exceeded the mean harvest index (43.11%). TCGS-584 × ICGV-99029 recorded the highest harvest index (63.09%). F_2 population *viz.*, ICGV-91114 × JL-220 registered the lowest harvest index (28.88%).

Among parents, TCGS-647 recorded the lower mean oil per cent (46.83%) and TIR-25 exhibited the highest (48.31%). Six parental genotypes exhibited more mean oil per cent than parental general mean (47.77%). Among the F_1s, it ranged from 46.37% (ICGV-99029 × TCGS-647) to 48.47% (TIR-25 × JL-220) and fifteen F_1s exceeded the general mean (47.63%) of F_1s. Mean oil per cent ranged from 46.80% to 48.40% among the F_2 s with a general mean value of 47.63%. K-1375 × TCGS-647 and TIR-25 × ICGV-91114 recorded the lowest (46.0%) and highest (48.40%) mean oil per cent respectively. F_2 populations derived from fifteen crosses had higher oil per cent than general mean of F_2 populations.

The parental genotype, K-1375 (25.73%) recorded the lowest and JL-220 the highest protein content (26.30%) with the general mean of 26.16%. Six parents had higher protein content than parental mean. Protein content ranged from 26.07% to 26.67% among the F_1s with a general mean of 26.41%, which was surpassed by thirteen F_1s. The F_1, JL-220 × TCGS-647 had the highest protein content (26.67%) and it was lowest (26.07%) in TPT-4 × TIR-25. protein content ranged from 26.03% to 26.73% with a overall mean of 26.45% in F_2 generation. Seventeen F_2 populations mean exceeded the mean protein content (26.45%). JL-220 × TCGS-647 recorded the highest protein content (26.73%). F_2 population *viz.*, ICGV-91114 × TCGS-584 registered the lowest harvest index (26.03%).

Among parents, kernel yield per plant varied from 12.87g (TCGS-647) to 18.36g (TPT-4) with a general mean of 15.06g. Four parental genotypes had higher kernel yield per plant than general mean (Table 1). The F_1, TCGS-584 × TCGS-647 recorded as low as 14.40g mean kernel yield per plant while TPT-4 × TIR-25 registered maximum kernel yield of 22.60g per plant with the general mean being 17.84g. Fifteen F_1s had more kernel yield per plant than F_1 general mean. In F_2 generation kernel yield per plant ranged from 10.78 g (ICGV-91114 × TCGS-584) to 20.45g (JL-220 × TCGS-647). Thirteen F_2 populations had more mean kernel yield per plant than general mean (15.27g).

The mean pod yield per plant ranged between 16.37g (TCGS-584) and 22.63g (TPT-4) with a general mean of 19.27 g among parents. Among F_1s, TIR-25 × ICGV-91114 recorded the lowest (17.97g) and the highest (27.67g) pod yield per plant, respectively. Fourteen F_1s had higher mean pod yield per plant than general mean (22.77g). Among F_2 populations, the range of variation was between 14.11g to 25.59g with a general mean of 19.91g. The F_2 populations ICGV-91114 × TCGS-584 registered the lowest mean pod yield per plant (14.11g) while JL-220 × TCGS-647 recorded the highest pod yield per plant (25.59g). Fourteen F_2 populations had higher mean pod yield per plant than F_2 general mean (19.91g).

Heterosis and inbreeding depression

For days to 50 per cent flowering all the crosses exhibited significant negative heterosis coupled with negative inbreeding depression (Table 2). The F_1s, JL -220 × K-1375 and JL-220 × TCGS-647 registered the highest significant positive hetrosis over better parent. TIR-25 × ICGV-99029 showed high negative relative heterosis and heterobeltiosis coupled with positive inbreeding depression indicating the expression of non-additive gene action in the expression of this character.

Five and eleven F_1s registered significant positive heterosis for days to maturity over mid-parent and better parent. Sixteen F_1s showed significant positive heterosis over standard parent. The F_1s, TCGS-584 × K-1375 registered highest significant relative heterosis (2.10%) and ICGV-91114 × TCGS-647 registered the highest significant positive heterobeltiosis (8.00%).

For number of well-filled and mature pods per plant seven and six F_1s showed significant positive heterosis over mid-parent and better parent. None of the F_1 showed significant positive heterosis over standard parent. Majority of the crosses recorded positive inbreeding depression. The F_1, TCGS-584 × TCGS-647 had exhibited highest positive significant heterosis over mid-parent (44.86%) and better parent (47.44%) coupled with positive inbreeding depression indicating the importance of additive gene effects for inheritance of this character. These results are in agreement with those reported by Deshmukh et al. (1985), Nadaf et al. (1988), Senthil and Vindhiyavarman (1998), Nagda and Sharma (2001) and Jayalakshmi and Reddy (2005).

For shelling per cent as many as nine and ten F_1s showed significant positive heterotic expression over mid-parent and better parent respectively. The F_1, ICGV-99029 × TXGS-647 was recorded significant positive heterosis over mid-parent and better parent coupled with positive inbreeding depression indicating the importance of additive gene action for the expression of shelling per cent. Heterosis for shelling per cent over mid-parent was reported by Garet (1976), Nadaf et al. (1988), Varman and Raveendran (1997), Parmar et al. (2000), Hariprasanna et al. (2008) and Jivani et al. (2008).

Out of twenty eight F_1s, seven and thirteen F_1s recorded significant positive heterosis over mid-parent and better parent respectively. The F_1, JL-220 × TCGS-647 exhibited the highest significant positive relative heterosis and heterobeltiosis coupled with low inbreeding depression indicating the importance of additive gene action in the expression of this character. Similar results were reported by Dasaradha Rami Reddy and Suneetha (2004) for SMK per cent in groundnut.

Six and nine F_1s expressed significant positive heterosis over mid-parent and better parent for hundred kernel weight. TCGS-584 × K-1375 had exhibited significant positive relative heterosis (35.35%) and heterobeltiosis (26.76%) with positive inbreeding depression indicating the importance of additive gene action in expression of this character. These results were confirmed with the findings of Parmar et al. (2000), Jivani et al. (2007) and Jivani et al. (2008) in groundnut. For dry haulms yield per plant seven, fifteen and sixteen F_1s recorded the significant positive heterosis over mid-parent, better parent and standard parent respectively. The F_1, ICGV-99029 × TCGS-647 expressed the highest significant positive relative heterosis (62.54%), heterobeltiosis (57.19%) and standard heterosis (147.14%) with very high positive inbreeding depression. These crosses can yield transgressive segregants in succeeding generation due to presence of high proportion of fixable alleles in them. Earlier Nagda and Sharma (2001) reported for dry haulms yield per plant.

Most of the F_1s for harvest index exhibited significant negative heterosis better parent and non-significant negative heterosis over mid-parent coupled with negative inbreeding depression, indicating the presence of non-additive gene action in the inheritance of this character. The findings corroborate with the results of Swe and Branch (1986), Suresh Kumar (1993) and Ahmed (1995).

Table 2. Estimates of heterosis and inbreeding depression for yield and yield traits in groundnut.

Crosses	Days to 50% flowering				Days to maturity				No. of well filled and mature pods per plant			
	Heterosis (%)			IBD (%)	Heterosis (%)			IBD (%)	Heterosis (%)			IBD (%)
	>MP	>BP	>MP		>SP	>BP	>MP		>SP	>BP	>MP	
TPT-4 × TPT-25	-16.38**	-11.90**	-11.90**	2.70	-2.48**	-0.32**	-0.32	0.63	16.70**	6.52**	6.52	44.89
TPT-4 × ICGV-91114	-12.20**	-10.00**	-14.29**	1.39	-2.60**	0.00	-5.06**	0.67	10.74*	3.32**	3.32	16.62
TPT-4 × TCGS-584	-10.18**	-9.64**	-10.71**	2.67	-2.41**	-0.98	-3.80**	-0.66	7.00	-19.34**	-19.34**	41.31
TPT-4 × JL-220	-13.25**	-12.20**	-14.29**	-2.78	-1.58**	-1.58**	-1.58**	0.00	-32.65**	-41.28**	-41.28**	33.96
TPT-4 × ICGV-99029	-15.22**	-7.14**	-7.14**	8.97	-1.81**	3.16**	3.16**	0.31	-26.16**	-45.08**	-45.08**	11.88
TPT-4 × K-1375	-12.99**	-8.33**	-8.33**	0.00	0.77	3.48**	3.48**	0.61	3.65	-3.91**	-3.91	54.00
TPT-4 × TCGS-647	-13.33**	-7.14**	-7.14**	-1.28	2.74**	6.65	6.65**	0.30	-23.57**	-43.06**	-43.06**	11.46
TIR-25 × ICGV-91114	-7.51**	0.00	-4.76**	3.75	-2.54**	2.33**	-2.85**	-0.65	-37.31**	-38.761*	-46.98**	-8.52
TIR-25 × TCGS-584	-7.95**	-2.41	-.357*	2.47	-3.30**	0.33	-2.53**	-1.30	-17.97*	-33.76**	-45.31**	18.98
TIR-25 × JL-220	-7.43**	-1.22	-3.57*	4.94	-5.88**	-3.80**	-3.80**	-4.61	-29.40**	-32.90**	-44.60**	-10.09
TIR-25 × ICGV-99029	-18.13**	-15.05**	-5.95**	1.27	0.00	2.73**	7.28**	0.00	22.49**	-2.59**	-19.57**	36.17
TIR-25 × K-1375	-13.98**	-13.98**	-4.76**	3.75	-0.75	-0.30	4.11**	0.91	-15.40**	-6.816**	-28.94**	19.43
TIR-25 × TCGS-647	-16.40**	-15.05**	-5.95**	-2.53	-1.79**	-0.30**	4.11**	-0.30	-14.1569	-31.61**	-43.54**	9.14
ICGV-91114 × TCGS-584	-5.52**	-3.75**	-8.33**	2.60	-0.16	1.00	4.11**	0.99	-18.83**	-35.62**	-44.25**	10.94
ICGV-91114 × JL-220	-4.94**	-3.75**	-8.33**	1.30	-0.32	2.33**	-2.85**	-0.33	-31.61**	-36.44**	-44.96**	0.50
ICGV-91114 × ICGV-99029	-15.56**	-5.00**	-9.52**	-5.26	-1.85**	6.00**	0.63	4.09	-26.03**	-42.19**	-49.94**	2.58
ICGV-91114 × K-1375	-12.14**	-5.00**	-9.52**	7.89	-1.11*	44.33**	-0.95	2.24	-16.55**	-17.12**	-28.23**	30.10
ICGV-91114 × TCGS-647	-19.32**	-11.25**	-15.48**	-8.45	1.25*	8.00**	2.53**	1.54	34.91**	5.62**	-8.54	57.00
TCGS-584 × JL-220	-9.09**	-8.54**	-10.71**	1.33	1.12*	2.61	-0.32	1.27	-11.85	-25.84**	-44.84**	5.18
TCGS-584 × ICGV-99029	-12.57**	-3.61**	-4.76**	-1.25	0.15	6.84**	3.80**	-0.30	5.36	3.27**	-47.57**	-23.19
TCGS-584 × K-1375	-14.77**	-9.64**	-10.71**	-2.67	2.81**	7.17	4.11**	-0.91	-16.73*	-33.61**	-43.30**	2.09
TCGS-584 × TCGS-647	-15.08**	-8.43**	-9.52**	0.00	1.08*	6.51**	3.48**	0.00	47.44**	44.86**	-26.45**	44.74
JL-220 × ICGV-99029	-14.29**	-4.88**	-7.14**	-2.56	-2.41**	2.53	2.53**	1.23	-15.99*	-30.46**	-48.28**	20.99
JL-220 × K-1375	-5.14**	1.22**	-1.19	3.61	-2.62**	-0.00**	0.00	-0.95	-35.86**	-40.00**	-48.75**	13.82
JL-220 × TCGS-647	-6.74**	1.22**	-1.19	0.00	-1.52**	2.22**	2.22**	-3.72	27.88**	6.06**	-21.12**	41.22
ICGV-99029 × K-1375	-0.52	3.23	14.29**	2.08	-1.32**	0.90	6.33**	-2.08	-19.72**	-36.94**	-46.14**	1.39
ICGV-99029 × TCGS-647	-3.06*	-1.04	13.10**	5.26	-0.87	0.29	7.91**	-0.88	35.44**	35.11**	-33.81**	23.89
K-1375 × TCGS-647	-6.88**	-5.38**	4.76**	-3.41	-0.15	0.90	6.33**	-9.82	-23.74**	-40.00**	-48.75**	10.74
S.E.	0.57	0.66	0.66	0.66	0.80	0.93	0.93	2.34	2.03	2.34	2.34	1.93

* Significant at 5% level; MP = Mid-parent; ** Significant at 1% level; BP = Better parent; SP = Standard parent.

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Table 2 Contd…

Crosses	Shelling per cent				Sound mature kernel per cent				100-kernel weight			
	Heterosis (%)			IBD (%)	Heterosis (%)			IBD (%)	Heterosis (%)			IBD (%)
	>MP	>BP	>MP		>SP	>BP	>MP		>SP	>BP	>MP	
TPT-4 × TPT-25	1.59	0.40**	0.40	2.02	1.31	0.14**	0.14	3.75	-4.21	-13.48**	-13.47**	-3.34
TPT-4 × ICGV-91114	2.03	0.28**	0.28	1.05	-1.44	-3.17**	-3.17	0.16	0.73	-5.20**	-5.20	-2.27
TPT-4 × TCGS-584	-3.51	-5.13**	-5.13**	-0.42	4.75*	3.03**	3.03	5.03	10.75*	-4.79**	-4.79	11.72
TPT-4 × JL-220	2.44	-0.32**	-0.32	6.05	-7.65**	-8.95**	-8.95**	-3.73	-3.90	-6.00**	-6.00	8.03
TPT-4 × ICGV-99029	1.80	-2.51**	-2.51	6.52	0.66	-2.21**	-2.21	1.51	-2.31	-7.01**	-7.01	4.77
TPT-4 × K-1375	1.20	-0.02**	-0.02	5.26	2.29	-1.88**	-1.88	1.21	2.19	-6.80**	-6.80	8.86
TPT-4 × TCGS-647	4.24*	-2.04**	-2.04	1.63	6.66**	-1.01**	-1.01	2.24	-1.72	-8.17**	-8.17*	-13.04
TIR-25 × ICGV-91114	2.12	1.55**	-0.83	0.52	-3.90	-4.50**	-6.69**	-4.74	4.40	-0.08**	-11.84**	1.27
TIR-25 × TCGS-584	-1.56	-2.07**	-4.37*	-0.06	-0.26	-0.77**	-3.05	1.97	15.16**	8.94**	-12.14**	15.58
TIR-25 × JL-220	-1.76	-3.30**	-5.56**	-3.26	-2.30	-2.55**	-4.79*	-6.00	-7.39	-14.64**	-18.37**	-5.63
TIR-25 × ICGV-99029	-3.42	-6.44**	-8.63**	-6.21	0.95	-0.81**	-3.08	3.11	9.15	3.28**	-6.66	5.88
TIR-25 × K-1375	-2.15	-2.18**	-4.47*	-0.33	4.26	1.14**	-1.19	-0.64	8.80	7.65**	-11.30**	1.38
TIR-25 × TCGS-647	2.42	-2.67**	-4.95**	-2.29	2.22	-4.11**	-6.31**	5.97	-15.53**	-18.56**	-29.24**	-26.44
ICGV-91114 × TCGS-584	-5.60**	-5.64**	-8.81**	-2.56	2.65	2.54**	-0.84	7.82	11.54*	1.24**	-10.68**	5.29
ICGV-91114 × JL-220	4.14*	3.08**	-0.46	5.49	1.98	1.61**	-1.24	-0.44	-7.39	-10.98**	-14.86**	-2.39
ICGV-91114 × ICGV-99029	5.39**	2.64**	-0.88	5.55	2.49	1.33**	-2.23	0.22	1.65	0.44**	-9.22*	2.29
ICGV-91114 × K-1375	-3.76*	-4.26**	-6.57**	-5.70	1.61	-0.83**	-4.31*	-4.41	6.11	2.60**	-9.48*	-5.66
ICGV-91114 × TCGS-647	4.59*	-0.08**	-3.56*	1.59	11.04**	4.78**	1.10	4.74	4.04	3.25**	-8.91*	6.97
TCGS-584 × JL-220	2.79	1.71**	-1.71	7.91	1.46	1.20**	-1.64	3.34	9.56*	-4.02**	-8.210*	18.12
TCGS-584 × ICGV-99029	-2.56	-5.13**	-8.32**	4.90	-5.27*	-6.45**	-9.53**	-3.66	2.80	-7.69**	-16.57**	2.21
TCGS-584 × K-1375	-3.76*	-4.23**	-6.54**	-3.06	3.74	1.14**	-2.20	4.12	35.35**	26.76**	4.44	18.69
TCGS-584 × TCGS-647	4.62*	-0.08**	-3.44	6.76	5.60*	-0.46**	-3.75	0.90	2.05	-6.74**	-18.97**	2.27
JL-220 × ICGV-99029	3.88*	2.19**	-3.32	-1.39	2.98	1.45**	-1.39	-4.31	-3.29	-5.95**	-10.05*	0.00
JL-220 × K-1375	-0.85	-2.36**	-4.71**	-3.47	1.35	-1.44**	-4.20	-2.72	-3.01	-9.73**	-13.67**	-3.53
JL-220 × TCGS-647	6.57**	2.81**	-2.73	-0.74	12.42**	5.72**	2.75	2.12	0.06	-4.51**	-8.68*	1.90
ICGV-99029 × K-1375	3.08	-0.12**	-2.52	5.36	-3.38	-4.64**	-10.06**	0.98	-1.80	-6.14**	-15.17**	-5.14
ICGV-99029 × TCGS-647	6.04**	3.95**	-4.84**	10.85	9.12**	4.09**	-1.84	1.57	-2.11	-4.00**	-13.24**	1.88
K-1375 × TCGS-647	6.23**	0.98**	-1.45	0.79	8.36**	4.67**	-3.85	-1.08	10.49*	7.63**	-6.4842	3.44
S.E.	2.13	2.46	2.46	2.13	2.89	3.34	3.34	3.16	3.21	3.71	3.71	3.43

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Table 2 Contd…

Crosses	Dry haulms yield per plant				Harvest index				Oil per cent			
	Heterosis (%)			IBD (%)	Heterosis (%)			IBD (%)	Heterosis (%)			IBD (%)
	>MP	>BP	>MP		>SP	>BP	>MP		>SP	>BP	>MP	
TPT-4 × TPT-25	31.99*	22.72**	42.78**	19.60	0.05	-6.48**	7.55	1.57	-0.49	-0.78**	-0.21	0.35
TPT-4 × ICGV-91114	28.94	22.60**	35.97*	-8.86	23.88**	16.44**	32.34**	0.23	-0.05	-0.42**	-0.42	0.07
TPT-4 × TCGS-584	-5.15	-7.08**	-7.08	-45.01	-23.97**	-29.97**	-16.84	-68.98	-1.25**	-1.39**	-1.39**	-0.91
TPT-4 × JL-220	4.82	0.50**	9.54	28.26	9.74	5.03**	14.90	14.30	-0.96*	-1.04**	-1.04**	-0.49
TPT-4 × ICGV-99029	-20.55	-35.01**	2.18	-15.81	-17.55*	-30.93**	2.28	-30.44	-1.35**	-1.46**	-1.46**	0.07
TPT-4 × K-1375	11.19	-0.43**	25.89	21.71	-3.96	-16.52**	13.03	-4.34	-0.90*	-1.11**	-1.11**	-0.84
TPT-4 × TCGS-647	20.53	1.30**	48.77**	23.55	-3.18	-18.14**	18.45*	9.03	0.94*	-0.69**	-0.69	1.54
TIR-25 × ICGV-91114	-12.71	-14.75**	-0.82	-20.47	2.02	1.43**	16.64	-7.18	0.22	-0.43**	0.14	-0.62
TIR-25 × TCGS-584	28.37	17.10**	36.24*	20.40	11.60	9.84**	30.44**	-5.85	0.13	-0.30**	0.28	0.14
TIR-25 × JL-220	52.84**	48.01**	72.21**	36.65	27.72**	24.61**	43.30**	28.77	0.69	0.32**	0.90*	0.76
TIR-25 × ICGV-99029	3.78	-9.71**	41.96*	8.83	-2.17	-13.10**	28.70**	6.63	-0.88*	-1.26**	-0.69	0.00
TIR-25 × K-1375	-10.66	-14.22**	8.45	0.43	-5.62	-12.73**	18.16*	-7.95	0.06	-0.43**	0.14	-0.55
TIR-25 × TCGS-647	20.29	7.79**	58.31**	17.06	4.74	-6.01**	36.00**	0.03	1.00*	-0.92**	-0.35	0.00
ICGV-91114 × TCGS-584	28.59	19.90**	32.97*	29.14	3.61	1.39**	20.40*	-4.42	-0.32	-0.56**	-0.83*	-0.49
ICGV-91114 × JL-220	17.22	16.22**	28.88	36.62	13.21	11.09**	26.26**	32.59	-0.17	-0.47**	-0.62	0.49
ICGV-91114 × ICGV-99029	61.38**	37.61**	116.35**	35.34	25.60**	11.00**	64.38**	15.80	-0.64	-0.90**	-1.11**	0.35
ICGV-91114 × K-1375	34.10*	25.86**	59.13**	21.83	4.43	-3.95**	30.03**	-4.81	-2.84**	-2.10**	-3.40**	-2.44
ICGV-91114 × TCGS-647	-1.69	-13.73**	26.70	3.76	-12.29	-21.69**	13.30	-2.15	0.62	-0.65**	-1.39**	-0.07
TCGS-584 × JL-220	-11.17	-16.50**	-8.99	-15.84	-12.22	-15.67**	0.14	-18.39	0.08	0.02**	-0.14	-0.21
TCGS-584 × ICGV-99029	10.23	-11.27**	39.51*	-63.54	-2.97	-12.58**	29.46**	-43.62	-0.52	-0.56**	-0.76	0.42
TCGS-584 × K-1375	51.23**	32.97**	68.12**	13.06	-0.26	-6.39**	26.74**	-21.01	0.07	0.00**	-0.28	0.90
TCGS-584 × TCGS-647	1.23	-16.33**	22.89	13.75	4.55	-4.82**	37.71**	4.88	0.94*	-0.56**	-0.83*	1.40
JL-220 × ICGV-99029	-23.85	-35.53**	1.36	-27.55	-20.73**	-31.08**	2.06	-30.59	-0.72	-0.74**	-0.90*	-0.49
JL-220 × K-1375	-17.59	-23.28**	-3.00	12.72	-15.90*	-23.97**	2.94	6.54	-0.13	-0.26**	-0.42	-0.63
JL-220 × TCGS-647	24.39	8.35**	59.13**	33.54	6.70	-6.31**	35.56**	29.07	1.24**	-0.33**	-0.46	1.81
ICGV-99029 × K-1375	-2.21	-11.79**	38.69*	6.88	-11.50	-15.30**	25.43**	-4.17	-1.91**	-2.02**	-2.22**	-0.50
ICGV-99029 × TCGS-647	62.54**	57.19**	147.14**	35.02	8.18	6.94**	58.37**	0.25	-1.78**	-3.27**	-3.47**	-2.23
K-1375 × TCGS-647	55.93**	45.08**	113.08**	10.20	2.84	-0.46**	44.02**	-16.68	1.30**	-0.14**	-0.56	2.02
S.E.	2.95	3.40	3.40	3.17	4.48	5.17	5.17	5.61	0.28	0.32	0.32	0.34

Contd…

Table 2 Contd…

Crosses	Protein per cent				Kernel yield per plant				Pod yield per plant			
	Heterosis (%)			IBD (%)	Heterosis (%)			IBD (%)	Heterosis (%)			IBD (%)
	>MP	>BP	>MP		>SP	>BP	>MP		>SP	>BP	>MP	
TPT-4 × TPT-25	-0.45	-0.51**	-0.51	-0.90	32.33**	23.09**	23.09**	16.92	30.50**	22.26**	22.26**	14.40
TPT-4 × ICGV-91114	1.34**	1.27**	1.27*	-0.38	-0.53	-4.28**	-4.28	-4.61	-2.27	-4.51**	-4.51	-2.22
TPT-4 × TCGS-584	1.02*	0.89**	1.15*	0.38	33.21**	13.40**	13.40*	37.64	31.38**	13.20**	13.20*	35.30
TPT-4 × JL-220	0.95	0.76**	1.15*	-0.25	16.26*	5.45**	5.45	27.31	15.60*	5.41**	5.41	23.27
TPT-4 × ICGV-99029	1.27*	1.15**	1.15*	-0.75	14.12*	5.07**	5.07	31.16	16.10*	7.59**	7.59	27.05
TPT-4 × K-1375	2.18**	1.27**	1.27*	1.63	15.52*	-0.82**	-0.82	19.62	27.86**	14.48**	14.48*	26.85
TPT-4 × TCGS-647	1.33**	1.15**	1.53**	0.13	22.92**	4.56**	4.56	12.31	18.82*	6.64**	6.64	10.72
TIR-25 × ICGV-91114	0.64	0.64**	0.51	-0.51	-11.10	-14.18**	-20.66**	-10.92	-13.13	-16.80**	-20.61**	-11.71
TIR-25 × TCGS-584	0.32	0.13**	0.38	-0.63	9.19	-0.82**	-14.67*	10.32	10.69	1.16**	-11.62	11.62
TIR-25 × JL-220	-0.25	-0.51**	-0.13	-0.89	4.97	2.13**	-12.13*	-6.92	8.08	4.99**	-8.28	-5.43
TIR-25 × ICGV-99029	1.08*	1.02**	0.89	0.25	17.04*	15.74**	-0.42	7.80	26.44**	24.97**	9.18	14.33
TIR-25 × K-1375	1.35**	0.51**	0.38	0.25	18.15*	8.31**	-6.81	0.95	17.34*	11.77**	-2.36	1.95
TIR-25 × TCGS-647	-0.00	-0.25**	0.13	0.51	16.03*	5.30**	-9.40	-6.83	13.04	7.96**	-5.69	-0.66
ICGV-91114 × TCGS-584	0.32	0.13**	0.38	1.01	5.78	-6.91**	-13.94*	31.79	11.35	-2.13**	-6.61	33.22
ICGV-91114 × JL-220	0.25	-0.00**	0.38	-1.27	19.25**	12.12**	3.65	12.87	17.88*	9.82**	4.79	8.46
ICGV-91114 × ICGV-99029	1.59**	1.53**	1.40**	-0.13	19.47**	14.10**	5.48	14.23	16.58*	10.42**	5.36	7.97
ICGV-91114 × K-1375	1.61**	0.76**	0.64	-0.88	33.20**	18.26**	9.33	32.56	31.57**	20.30**	14.79*	34.68
ICGV-91114 × TCGS-647	1.40**	1.14**	1.53**	-0.50	40.50**	23.53**	14.20*	34.39	30.35**	19.48**	14.01*	21.90
TCGS-584 × JL-220	0.32	0.25**	0.64	-0.63	15.07	7.21**	-12.75*	12.69	12.36	5.51**	-13.10*	2.80
TCGS-584 × ICGV-99029	1.40**	1.14**	1.40**	0.25	6.80	-2.01**	-17.56**	5.02	10.70	2.26**	-12.74	-0.32
TCGS-584 × K-1375	1.54**	0.51**	0.76	0.00	47.47**	45.97**	4.68	30.19	48.86**	42.51**	12.68	33.14
TCGS-584 × TCGS-647	1.08*	1.01**	1.40**	0.63	11.74	11.63**	-21.57**	18.94	21.98*	16.47**	-7.39	24.30
JL-220 × ICGV-99029	0.32	-0.00**	0.38	-0.76	2.45	0.78**	-15.21*	-6.34	4.51	2.69**	-12.37	-5.56
JL-220 × K-1375	2.24**	1.14**	1.53**	0.50	16.87*	9.93**	-10.53	7.75	16.99*	14.65**	-5.57	11.23
JL-220 × TCGS-647	1.39**	1.39**	1.78**	-0.25	10.49	2.83**	-16.30**	-33.08	6.46	4.61**	-13.83*	-31.25
ICGV-99029 × K-1375	1.67**	0.89**	0.64	-0.76	36.91**	26.80**	6.68	13.31	31.64**	26.81**	8.2044	8.66
ICGV-99029 × TCGS-647	-0.45	-0.76**	-0.38	-1.66	16.43*	6.73**	-10.20	15.85	14.74	10.82**	-5.44	8.19
K-1375 × TCGS-647	1.36**	0.25**	0.64	0.63	57.61**	55.85**	11.76	42.40	37.12**	36.74**	8.72	16.85
S.E.	0.19	0.22	0.22	0.23	1.66	1.91	1.91	2.20	2.22	2.56	2.56	2.54

* Significant at 5% level; MP = Mid-parent; ** Significant at 1% level; BP = Better parent; SP = Standard parent.

Table 3. List of best parents and F_1s for yield and yield traits in groundnut.

Character	Best parent – based on	Best cross – based on	Best heterotic crosses-based on		
	Per se performance	*Per se* performance	Relative heterosis	Heterobeltiosis	Standard heterosis
Days to 50 per cent flowering	JL-220 ICGV-91114 TCGS-584	ICGV-91114 × TCGS-647 TPT-4 × TIR-25 TPT-4 × JL-220	TIR-25 × ICGV-990129 TPT-4 × TIR-25 ICGV-91114 × ICGV-99029	TIR-25 × ICGV-99029 TIR-25 × TCGS-647 TIR-25 × K-1375	ICGV-9111 × TCGS-647 TPT-4 × ICGV-91114 TPT-4 × JL-220
Days to maturity	ICGV-91114 TCGS-584 JL-220	TPT-4 × ICGV-91114 ICGV-91114 × TCGS-584 TPT-4 × TCGS-584	TIR-25 × JL-220 TIR-25 × TCGS-584 TIR-25 × ICGV-91114	TIR-25 × JL-220 TPT-4 × JL-220 TPT-4 × TCGS-584	TPT-4 × ICGV-91114 TPT-4 × TCGS-584 TIR-25 C JL-220
Number of well-filled and mature pods per plant	TPT-4 ICGV-91114 K-1375	TPT-4 × TIR-25 TPT-4 × ICGV-91114 TPT-4 × K-1375	TCGS-584 × TCGS-647 ICGV-99029 × TCGS-647 JL-220 × TCGS-647	TCGS-584 × TCGS-647 ICGV-99029 × TCGS-647 TPT-4 × TIR -25	TPT-4 × TIR-25 TPT-4 × ICGV-91114
Shelling per cent	TPT-4 TIR-25 K-1375	TPT-4 × TIR-25 TPT-4 × ICGV-91114 TPT-4 × K-1375	JL-220 × TCGS-647 K-1375 × TCGS-647 ICGV-99029 × TCGS-647	ICGV-99029 × TCGS-647 ICGV-91114 × JL-220 JL-220 × TCGS-647	TPT-4 × TIR-25 TPT-4 × ICGV-91114
Sound mature kernel per cent	TPT-4 TIR-25 JL-220	TPT-4 × TCGS-584 JL-220 × TCGS-647 ICGV-91114 × TCGS-647	JL-220 × TCGS-647 ICGV-91114 × TCGS-647 ICGV-99029 × TCGS-647	JL-220 × TCGS-647 ICGV-91114 × TCGS-647 K-1375 × TCGS-647	TPT-4 × TCGS-584 JL-220 × TCGS-647 TPT-4 × TIR-25
100-kernel weight	TPT-4 JL-220 ICGV-99029	TCGS-584 × K-1375 TPT-4 × TCGS-584 TPT-4 × ICGV-91114	TCGS-584 × K-1375 TIR-25 × TCGS-584 ICGV-911114 × TCGS-584	TCGS-584 × K-1375 TIR-25 × TCGS-584 K-1375 × TCGS-647	TCGS-584 × K-1375
Dry haulm weight per plant	ICGV-99029 TCGS-647 K-1375	ICGV-99029 × TCGS-647 ICGV-91114 × ICGV-99029 K-1375 × TCGS-647	ICGV-99029 × TCGS-647 ICGV-911114 × ICGV-99029 K-1375 × TCGS-647	ICGV-99029 × TCGS-647 TIR-25 × JL-220 K-1375 × TCGS-647	ICGV-99029 × TCGS-647 ICGV-911114 × ICGV-99029 K-1375 × TCGS-647
Harvest index	ICGV-99029 TCGS-647 K-1375	ICGV-91114 × ICGV-99029 ICGV-99029 × TCGS-647 K-1375 × TCGS-647	TIR-25 × JL-220 ICGV-911114 × ICGV-99029 TPT-4 × ICGV-91114	TIR-25 × JL-220 TPT-4 × ICGV-91114 ICGV-91114 × JL-220	ICGV-911114 × ICGV-99029 ICGV-99020 × TCGS-647 K-1375 × TCGS-647
Oil per cent	TIR-25 TPT-4 JL-220	TIR-25 × JL-220 TIR-25 × TCGS-584 TIR-25 × ICGV-91114	ICGV-99029 × TCGS-647 JL-220 × TCGS-647 TIR-25 × TCGS-647	TIR-25 × JL-220 TCGS-584 × JL-220 TCGS-584 × K-1375	TIR-25 × JL-220 TIR-25 × TCGS-584 TIR-25 × ICGV-91114
Protein content	JL-220 TCGS-647 TCGS-584	JL-220 × TCGS-647 TPT-4 × TCGS-647 ICGV-91114 × TCGS-647	JL-220 × K-1375 TPT-4 × K-1375 ICGV-99029 × K-1375	ICGV-91114 × ICGV-99029 JL-220 × TCGS-647 TPT-4 × ICGV-91114 TPT-4 × K-1375	JL-220 × TCGS-647 TPT-4 × TCGS-647 ICGV-91114 × TCGS-647 JL-220 × K-1375
Kernel yield per plant	TPT-4 ICGV-91114 TIR-25	TPT-4 × TIR-25 ICGV-91114 × TCGS-647 TPT-4 × TCGS-584	K-1375 × TCGS-647 TCGS-584 × K-1375 ICGV-91114 × TCGS-647	K-1375 × TCGS-647 TCGS-584 × K-1375 ICGV-99029 × K-1375	TPT-4 × TIR-25 ICGV-91114 × TCGS-647 TPT-4 × TCGS-584
Pod yield per plant	TPT-4 ICGV-91114 TIR-25	TPT-4 × TIR-25 ICGV-91114 × K-1375 ICGV-91114 × TCGS-647	TCGS-584 × K-1375 ICGV-99029 × K-1375 ICGV-91114 × K-1375	TCGS-584 × K-1375 K-1375 × TCGS-647 TIR-25 × ICGV-99029	TPT-4 × TIR-25 ICGV-91114 × K-1375 TPT-4 × K-1375

Out of twenty eight F_1s, only Five F_1s and two F_1s recorded the highest significant positive heterosis over mid-parent and better parent. The F_1, TIR-25 × TCGS-647 exhibited highest positive and significant heterosis over mid-parent coupled with low positive inbreeding depression, indicating the importance of additive gene action for this character. The results of Makne and Bhale (1991), Nagda and Sharma (2001) and Chen Silong Li et al. (2009) further confirm these findings.

For protein per cent seventeen, twenty two and twelve F_1s expressed significant positive heterosis over mid-parent, better parent and standard parent. The F_1, JL-220 x K-1375 recorded highest significant relative heterosis, ICGV-91114 × ICGV-99029 had exhibited highest significant positive heterobeltiosis, and JL-220 × TCGS-647 significant standard heterosis with positive inbreeding depression indicating the importance of additive gene action in expression of this character. Earlier Nagda and Sharma (2001) reported for protein per cent. Kernel yield per plant, eighteen and twenty two F_1s exhibited significant positive heterosis over mid-parent and better parent. The F_1, K-1375 × TCGS-647 recorded the highest significant positive heterosis over mid-parent (57.61%) and heterobeltiosis (55.86%) coupled with high positive inbreeding depression (42.40%) indicating the importance of additive gene action for this trait. Majority of the F_1s expressed positive inbreeding depression. Arunachalam et al. (1982), Isleib (1982), Reddi et al. (1989), Bansal et al. (1993), Jayalakshmi et al. (2000), Jayalakshmi and Reddy (2005), John and Vasanthi (2006), Jivani et al. (2008) and Jivani et al. (2009) also reported positive heterosis for pod and kernel yields in groundnut.

Out of twenty eight F_1s, sixteen, twenty five and five F_1s showed significant positive heterosis for pod yield per plant over mid-parent, better parent and standard parent respectively. The F_1, TCGS-584 × K-1375 registered the highest significant relative heterosis (48.86%) and heterobeltiosis (42.51%) coupled with high positive inbreeding depression indicating the importance of additive gene action for this character. Heterosis for pod yield in groundnut was also reported by Arunachalam et al. (1982), Deshmukh (1985), Reddi et al. (1989), Bansal et al. (1993), Varman and Raveendran (1997), Rudraswamy et al. (1999) and Parmar et al. (2004).

The results clearly indicated that the genotype, TPT-4 showed the highest *per se* performance for number of well-filled and mature pods per plant, shelling per cent, SMK per cent, 100-kernel weight, kernel yield per plant and pod yield per plant. The parent, ICGV-91114 recorded the lowest *per se* performance for days to 50 per cent flowering and days to maturity. The other parent, JL-220 recorded the highest *per se* performance for protein per cent. The genotypes, ICGV-99029 for dry haulms yield per plant and harvest index.

Among the F_1s, ICGV-91114 × TCGS-647 recorded the lowest *per se* performance for days to 50 per cent flowering and highest *per se* performance for SMK per cent (Table 1). TPT-4 × ICGV-91114 exhibited the lowest per se performance for days to maturity and other F_1s, JL-220 × ICGV-99029 for harvest index, ICGV-99029 × TCGS-647 for dry haulms yield per plant and TPT-4 × TIR-25 for number of well-filled and mature pods per plant, shelling per cent, kernel yield per plant and pod yield per plant exhibited the highest per se performance. TCGS-584 × JL-220 recorded the lowest per se performance for days to maturity.

Among the F_2s, TPT-4 × ICGV-91114 was distinct for its lowest mean value for days to maturity and highest mean values for number of well-filled and mature pods per plant, shelling per cent, 100- kernel weight. Other F_2s, involving TIR-25 as one of parents showing highest *per se* performance is TIR-25 × TCGS-647 for short statue, TIR-25 × ICGV-91114 for oil per cent. The F_2 involving JL-220 as one of the parents *viz*., JL-220 × ICGV-99029 for SCMR, JL-220 × TCGS-647 for SMK per cent, protein per cent, kernel yield per plant and pod yield per plant showed the highest *per se* performance.

The parent involving ICGV-91114 as one of the parent viz., ICGV-91114 × K-1375 came to flowering early and ICGV-91114 × TCGS-647 recorded the highest *per se* performance for protein per cent. In the present study the other F_2s viz., TCGS-584 × ICGV-99029 for dry haulms yield per plant and harvest index. It is clear from the per se performance of parents and F_1s that ICGV-99029 imparted high yielding ability to its cross with respect to number of well-filled and mature pods per plant, shelling per cent, kernel yield per plant and pod yield per plant.

From the forgoing discussion it can be concluded that, certain crosses recorded significant standard heterosis for certain yield and yield attributes *viz*., ICGV-99029 × TCGS-647 for dry haulms yield per plant, TIR-25 × JL-220 for oil per cent, JL-220 × TCGS-647 for protein per cent and TPT-4 × TIR-25 for kernel yield per plant. They had recorded the highest positive heterosis (Table 3). In all the above cross combinations that showed high heterosis involved one good general combiner and one poor combiner thereby indicating the roll of inter-allelic interactions. Therefore, for exploitation of such heterosis in future breeding programmes either recurrent selection or diallel selective mating system is to be examined in these crosses. Further, the crosses which recorded high heterosis for pod yield also recorded high inbreeding depression in F_2 generation indicating importance of non-additive gene action.

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