Identification of Heterotic Crosses for Water Use Efficiency Traits and Yield in Relation to Moisture Stress Tolerance in Groundnut

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Abstract: **Estimates of relative heterosis, heterobeltiosis and standard heterosis were obtained for twenty four crosses generated through L x T analysis for water use efficiency traits and yield. The crosses *viz.*, Narayani x Dharani with high relative heterosis and standard parent heterosis and Prasuna x TCGS-1416 with high better parent heterosis for pod yield per plant also expressed positive mid-parent, better parent and standard parent heterosis for root length. The other promising crosses exhibited high significant positive mid-parent, better parent and standard parent heterosis for certain attributes *viz.*, Prasuna x Dharani for SPAD chlorophyll meter reading at 40 days after sowing, TAG-24 x TMV-2 for SPAD chlorophyll meter reading at 60 days after sowing, TAG-24 x Dharani for relative water content at 40 days after sowing, K-6 x ICGV-91114 for relative water content at 60 days after sowing and Greeshma x TCGS-1416 for harvest index. TAG -24 x ICGV-91114showed significant negative heterosis for specific leaf area at 60 days after sowing. These hybrids offer best possibilities of future exploitation for development of high yielding moisture stress tolerant groundnut genotypes.**

Key words : **Relative heterosis, Heterobeltiosis, Standard heterosis, Water use efficiency traits, Groundnut.**

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). Groundnut is a highly self pollinated crop and the scope for exploitation of hybrid vigour will depend on the direction and magnitude of heterosis, biological and feasibility and nature of gene action. Study of heterosis will have a direct bearing on the breeding methodology to be employed for varietal improvement. Therefore, the present study was planned to estimate the extent of heterosis over mid parent, better parent and standard parent in twenty four F_1s for water use efficiency traits and yield.

MATERIALS AND METHODS

The experimental material comprised of 12 F_1 crosses of generated through Line x Tester analysis using six lines *viz.*, TAG-24, Prasuna, Rohini, Narayani, K-6 and Greeshma and four testers *viz.*, Dharani, TMV-2, TCGS-1416 and ICGV-91114. These were grown in a randomized block design with three replications during *kharif* 2014 at RARS, Tirupati. The F_1 hybrids were grown in plots consisting of single row of 5m length having a spacing of 30.0 × 10cm.

In parents and F_1 hybrids, twenty plants per replication per genotype per replication per cross were sampled for recording observation. Data were recorded for days to 50 per cent flowering, days to maturity, SPAD chlorophyll meter reading (at 40 and 60 DAS), specific leaf area ($cm^2 g^{-1}$) ((at 40 and 60 DAS), specific leaf weight (g cm^{-2}) (at 40 and 60 DAS), relative water content (%) (at 40 and 60 DAS), root length (cm), dry haulms weight per plant (g), harvest index (%) and pod yield per plant (g). The water use efficiency traits were measured on all four-leaflets of third leaf from the top on main axis at 40 and 60 DAS. Heterosis over mid parent (relative heterosis), better parent (heterobeltiosis) and standard parent (standard heterosis) in F_1 generation in each cross were estimated using standard formulae.

RESULTS AND DISCUSSION

Heterosis or hybrid vigour is measured as an increase or decrease of a trait mid- parental value (relative heterosis), over better parent (heterobeltiosis) and standard parent (standard heterosis) for water use efficiency traits and yield are computed and presented in Tables 1 and 2.

Days to 50 per cent flowering

The range of heterosis over mid parent varied from -9.50% (Narayani x Dharani) to 9.20% (Rohini x ICGV-91114). Significant positive heterosis was observed in two F_1s, while significant negative heterosis was noticed in four F_1 s (Table 1). The F_1, Rohini x ICGV-91114 recorded the highest significant positive heterosis over mid-parent. Heterobeltiosis for days to 50 per cent flowering ranged from –13.04% (Rohini x TCGS-1416) to 3.26% (TAG-24 x Dharani). Among twenty four F_1s studied, nine F1s exhibited significant negative heterosis over better parent. The F1, TAG-24 x Dharani recorded the highest positive heterosis over better parent. Standard heterosis ranged from –19.19% (Narayani x TCGS-1416) to -3.03% (Prasuna x TMV-2 and Prasuna x Dharani). Significant negative heterosis was noticed in twenty F_1 s.

Days to maturity

Relative heterosis ranged from –9.89% (K-6 x ICGV-911142) to 2.65% (TAG-24 x Dharani). Six F_1s exhibited positive non significant relative heterosis. Significant negative heterosis over mid-parent was observed in five F_1s. The minimum and maximum heterosis for days to maturity over better parent was observed in F_1s Greeshma x Dharani (-15.56%) and TAG-24 x Dharani (1.89%) respectively. Eighteen F_1s exhibited significant negative heterosis over better parent. Standard heterosis ranged from –

14.53% (Narayani x TMV-2) to 1.95% (TAG-24 x Dharani). Significant and negative heterosis over standard parent was observed in thirteen F_1s.

SPAD chlorophyll meter reading at 40 days after sowing

The range of heterosis over mid parent varied from -11.54% (Rohini x TMV-2) to 12.68% (Prasuna x Dharani). Significant positive heterosis was observed in four F_1s only, while significant negative heterosis was noticed in only three F_1s. Positive and non significant heterosis was noticed in seven F_1s. Eight F_1s exhibited non-significant negative heterosis over better parent. Heterobeltiosis for SCMR ranged from –11.28% (Rohini x TMV-2) to 15.02% (Prasuna x Dharani). Among twenty four F_1s studied, seven F_1s exhibited significant positive heterosis over better parent. Positive and non-significant heterosis was noticed in eight F_1s and six F_1s exhibited non significant negative heterosis over better parent. These results are in agreement with the results of Seethala Devi (2004).

SPAD chlorophyll meter reading at 60 days after sowing

The range of heterosis over mid parent varied from 17.00% (K-6 x ICGV-91114) to 15.25% (TAG-24 x TMV-2). Significant positive heterosis was observed in three F_1s and thirteen F_1s recorded significant and negative heterosis over mid-parent. Positive and non-significant heterosis was noticed in four F_1s and non-significant negative heterosis over better parent was observed in four F_1s. Heterobeltiosis for SPAD chlorophyll meter reading at 60 days after sowing ranged from -20.45% (K-6 x ICGv- 91114) to 15.25% (TAG-24 x TMV-2). Among twenty four F_1s studied, three F_1s exhibited significant positive heterosis over better parent. Thirteen F_1s recorded significant and negative heterosis over better parent. Positive and non-significant heterosis was noticed in only two F_1s and non significant negative heterosis over better parent was noticed four in four F_1s. Standard heterosis ranged from –12.50% (K-6 x ICGV-91114) to 15.25% (TAG-24 x TMV-2). Significant positive heterosis was observed in three F_1s. Significant negative heterosis was observed in nine F_1s. Positive and non significant heterosis was noticed in seven F_1s and non significant negative heterosis over better parent was noticed four in five F_1s. These results are in agreement with the results of Seethala Devi (2004).

Specific leaf area ($cm^2 g^{-1}$) at 40 days after sowingThe range of heterosis over mid-parent varied from 7.79% (Greeshma x TCGS-1416) to 97.19% (Rohini x Dharani). Out of twenty four F_1s, seventeen F_1s recorded significant positive heterosis over mid-parent and non significant positive heterosis was noticed in six F_1s. Non significant negative heterosis was noticed in only one F_1. Heterobeltiosis ranged from -20.00% (Greeshma x TCGS-1416) to 88.44% (Narayani x T CGS-1416).Significant and positive heterosis was observed in four F_1s. Significant negative heterosis was noticed in twenty F_1s. Standard heterosis ranged from -9.57% (Greeshma x TCGS-1416) to 128.57% (K-6 x Dharani). Out of twenty four F_1s, twenty three F_1s recorded significant positive heterosis over standard parent.

Specific leaf area ($cm^2 g^{-1}$) at 60 days after sowingThe range of heterosis over mid-parent varied from -28.93% (TAG-24 x ICGV-91114) to 28.42% (Rohini x Dharani). Out of twenty four F_1s, six F_1s recorded significant positive heterosis over mid-parent. Significant negative heterosis was noticed in fifteen F_1s. Heterobeltiosis ranged from 41.46% (TAG-24 x ICGV-91114) to 17.03% (Rohini x Dharani). Significant and positive heterosis was observed in seventeen F_1s. Significant negative heterosis was noticed in only three F_1s. Standard heterosis ranged from 0.68% (TAG-24 x ICGV-91114) to 97.19% (Rohini x Dharani). Out of twenty four F_1s twenty F_1s recorded significant positive heterosis over standard parent and significant negative heterosis was noticed in only one F_1.

Peanut genotypes with low SLA had more photosynthetic machinery and the potential for greater assimilation per unit leaf area and large genotypic differences in the rate of light saturated photosynthesis per unit area was reported by Wright and Bell (1992). Heterosis for SLA in groundnut was reported earlier by Pallas and Samish (1974), Bhagsari and Brown (1976) and Pallas (1982).

Specific leaf weight (g cm^{-2}) at 40 days after sowing

The relative heterosis for specific leaf weight varied from -57.14% (TAG-24 x TCGS- 1416) to 25.00% (K-6 x TCGS-1416). Four out of twenty four F_1s registered significant negative heterosis and six F_1s showed no significant positive heterosis. Heterobeltiosis ranged from -58.14% (K- x Dharani) to 0.09% (K-5 x TCGS-1416). Four F_1s, recorded significant negative heterosis while negative was observed. Standard heterosis ranged from -58.14% (Prasuna x TMV-2) to 0.00% (Greeshma x TCGS-1416). As many as seven F_1s recorded significant negative heterosis over standard parent.

Specific leaf weight (g cm^{-2}) at 60 days after sowing

The relative heterosis for specific leaf weight varied from -88.89% (TAG-24 x ICGV-91114) to 14.29%% (K-6 x TMV-2 and Greeshma x TMV-2). Only one out of twenty four F_1s registered significant negative heterosis. Heterobeltiosis ranged from -88.89% (TAG-24 x ICGV-91114) to 14.29%% (K-6 x TMV-2 and Greeshma x TMV-2). Only one F_1 recorded significant negative heterosis. Standard heterosis ranged from - 88.89% (TAG-24 x ICGV-91114) to 0.00% (Greeshma x Dharani and Greeshma x TCGS-1416). One F_1 recorded significant negative heterosis over standard parent.

Relative water content (%) at 40 days after sowing

The range of heterosis over mid-parent varied from –4.69% (TAG-24 x TCGS-1416) to 10.37% (TAG-24 x Dharani). Out of twenty four F_1s, six F_1s recorded significant positive heterosis over mid-parent. Significant negative heterosis was noticed in only three F_1s. Heterobeltiosis ranged from -5.06% (TAG-24 x TCGS-1416) to 9.73% (TAG-24 x Dharani). Significant and positive heterosis was observed in only one F_1. Significant negative heterosis was noticed in five F_1s. Standard heterosis ranged from –4.31% (TAG-24 x TCGS-1416 and Prasuna x Dharani) to 10.59% (TAG-24 x Dharani). Out of twenty four F_1s two F_1s recorded significant positive heterosis over standard parent and significant negative heterosis was also noticed in two F_1s.

Relative water content (%) at 60 days after sowing

The range of heterosis over mid-parent varied from –9.09% (TAG-24 x TMV-2) to 5.47% (K-6 x ICGV-91114). Out of twenty eight F_1s, two F_1s recorded significant positive heterosis over mid-parent. Significant negative heterosis was noticed in twelve F_1s. Heterobeltiosis ranged from -11.11% (TAG-24 x TMV-2) to 2.66% (K-6 x ICGV- 91114).

Significant negative heterosis was noticed in fourteen F_1s. Standard heterosis ranged from –9.02% (Greeshma x TMV-2) to 5.88% (K-6 x ICGV-91114). Out of twenty four F_1s, only one F_1 recorded significant positive heterosis over standard parent. Significant negative heterosis was noticed in eleven F_1s.

Root length (cm)

Relative heterosis ranged from –3.08% (Rohini x TCGS-1416) to 2.07% (Narayani x Dharani). None of the F_1s showed significant positive and significant negative heterosis over mid parent.

The F_1, Greeshma x ICGV-91114 recorded the lowest (-73.96%) and the highest heterosis by Narayani x Dharani (42.97%) over better parent, respectively. None of the F_1s showed significant positive and significant negative heterosis over better parent. Standard heterosis ranged from –28.00% (Rohini x TCGS- 1416) to 42.40% (Narayani x Dharani). Twenty F_1s recorded significant positive heterosis over standard parent

Dry haulm weight per plant (g)

The F_1s recorded minimum and maximum relative heterosis are K- x ICGV- 91114 (-46.89%) and Greeshma x Dharani (78.31%), respectively. Fifteen F_1s registered significant positive heterosis and seven F_1 s showed significant negative heterosis. Heterosis over better parent for dry haulm weight per plant ranged from 51.04% (K-6 x ICGV-91114) to 54.53% (Greeshma x Dharani). Nine F_1 s recorded significant positive heterosis and significant negative heterosis was observed in nine F_1s. Standard heterosis ranged from –16.36% (Rohini x TMV-2) to 162.36% (Prasuna x TMV-2). Twenty F_1s recorded significant positive heterosis heterosis while three F_1s exhibited significant and negative heterosis over standard parent.

Harvest index (%)

Relative heterosis ranged from -29.29% (Greeshma x ICGV-91114) to 42.93% (Greeshma x TCGS-1416). As many as ten F_1s recorded significant positive heterosis over mid parent while significant negative heterosis was observed in eleven F_1s. Heterobeltiosis was minimum in the $F_{1,}$ Greeshma x ICGV-91114 (-37.20%) and was maximum in Greeshma x TCGS-1416 (38.18%). Five F_1s recorded significant positive and fourteen F_1s negative heterosis over better parent, respectively. Standard heterosis ranged from –34.93% (Greeshma x ICGV-91114) to 19.06% (Greeshma x TCGS-1416). Significant and positive heterosis in desirable direction was observed in four F_1s.

Eleven F_1s recorded significant negative heterosis over standard parent. Earlier Vinit Vyas Nagda and Sharma (2001) reported for dry haulms yield per plant. The findings corroborate with the results of Swe and Branch (1986), Suresh Kumar (1993) and Nisar Ahmed (1995).

Pod yield per plant (g)

Relative heterosis ranged from -58.82% (Greeshma x ICGV-91114) to 77.73% (Narayani x Dharani). Nine F_1s recorded significant positive heterosis.

Nine F_1s recorded significant negative heterosis over mid parent. Heterobeltiosis ranged from -73.99% (Greeshma x ICGV-91114) to 60.69% (Prasuna x TCGS-1416). Seven F_1s recorded significant positive heterosis while thirteen F_1s registered significant negative heterobeltiosis. Standard heterosis ranged from –39.28% (Rohini x TMV-2) to 104.61(Narayani x Dharani). Seventeen F_1s recorded significant heterosis and fourn F_1s registered significant negative over standard parent. 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), Parmar *et al.* (2004), Sharma and Gupta (2008) and Jivani *et al.* (2009).

CONCLUSION

From the forgoing discussion it can be concluded that crosses Narayani x Dharani with high relative heterosis and standard parent heterosis and Prasuna x TCGS-1416 with high better parent heterosis for pod yield per plant also expressed positive mid-parent, better parent and standard parent heterosis for root length. The other crosses recorded high significant positive mid-parent, better parent and standard parent heterosis for certain attributes *viz.*, Prasuna x Dharani for SPAD chlorophyll meter reading at 40 days after sowing, TAG-24 x TMV-2 for SPAD chlorophyll meter reading at 60 days after sowing,

TAG-24 x Dharani for relative water content at 40 days after sowing, K-6 x ICGV-91114 for relative water content at 60 days after sowing and Greeshma x TCGS-1416 for harvest index. TAG -24 x ICGV-91114showed significant negative heterosis for specific leaf area at 60 days after sowing. These hybrids offer best possibilities of future exploitation for development of high yielding moisture stress tolerant genotypes.

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Table 1: Estimates of heterosis for water use efficiency traits and yield in groundnut

Crosses	Heterosis (%)					
	Days to 50% flowering			Days to maturity		
	Relative heterosis	Heterobeltiosis	Standard heterosis	Relative heterosis	Heterobeltiosis	Standard heterosis
TAG-24 x ICGV-91114	-7.45**	-12.12**	-12.12**	-0.95	-8.89**	-10.00**
TAG-24 x TMV-2	-1.14	-2.25	-12.12**	-8.95**	-9.06**	-11.92**
TAG-24 x TCGS-1416	1.66	0.00	-7.07*	0.00	0.00	1.92
TAG-24 x Dharani	4.97	3.26	-4.04	2.65	1.89	1.95
Prasuna x Dharani	-1.54	-3.03	-3.03	0.00	-1.85	1.92
Prasuna x ICGV-91114	-1.64	-6.25*	-9.09**	0.94	-10.93**	-12.88**
Prasuna x TMV-2	2.13	0.00	-3.03	-1.87	-2.78	0.96
Prasuna x TCGS-1416	-7.45**	-9.38**	-12.12**	-2.35	-3.70	0.00
Rohini x TMV-2	-0.57	-12.12**	-12.12**	-6.48*	-11.28**	--7.28**
Rohini x ICGV-91114	9.20**	2.30	-10.10**	-5.16	-12.83**	-10.78**
Rohini x Dharani	5.95*	-3.26	-10.10**	-10.14	-14.72**	-9.88**
Rohini x TCGS-1416	-4.76	-13.04**	-19.19**	-9.31	-7.44**	-3.53
Narayani x TCGS-1416	-6.45*	-12.12**	-12.12**	-2.79	-6.58*	-9.65**
Narayani x ICGV-91114	2.30	2.30	-10.10**	-3.79	-13.53**	-13.53**
Narayani x TMV-2	2.79	0.00	-7.07*	-2.75	-17.36**	-14.53**
Narayani x Dharani	-9.50**	-11.96**	-18.18**	-2.27	-4.44*	-3.53
K-6 x Dharani	-4.76	-9.09**	-9.09**	-4.44	-5.35*	-3.53
K-6 x TCGS-1416	-1.69	-3.33	-12.12**	-6.95*	-11.89**	-10.06**
K-6 x ICGV-91114	-4.40	-5.43	-12.12**	-9.89**	-12.15**	-11.00**
K-6 x TMV-2	4.40	3.26	-4.04	-4.90	-5.35*	-3.53
Greeshma x Dharani	-2.65	-7.07*	-7.07*	-2.19	-15.56**	-2.88
Greeshma x ICGV-91114	-1.69	-3.33	-12.12**	-1.14	-2.88	-12.88**
Greeshma x TCGS-1416	0.00	-1.09	-8.08**	-7.75**	-9.30**	-13.53**
Greeshma x TMV-2	-1.10	-2.17	-9.09**	-2.27	-4.44*	-3.53
S.E.	0.83	0.96	0.96	0.89	1.10	1.10

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Crosses	Heterosis (%)					
	SPAD chlorophyll meter reading at					
	40DAS			60DAS		
	Relative heterosis	Heterobeltiosis	Standard heterosis	Relative heterosis	Heterobeltiosis	Standard heterosis
TAG-24 x ICGV-91114	2.52	4.61*	6.78**	1.07	0.25	1.92
TAG-24 x TMV-2	11.64**	13.91**	16.27**	15.25**	15.25**	17.17**
TAG-24 x TCGS-1416	0.79	2.44	8.47**	-11.02**	-14.39**	-5.83*
TAG-24 x Dharani	2.01	2.67	7.63**	0.41	-0.41	1.25
Prasuna x Dharani	12.68**	15.02**	17.46**	0.83	0.00	1.67
Prasuna x ICGV-91114	7.32**	9.54**	11.86**	-4.10	-4.10	-2.50
Prasuna x TMV-2	1.97	3.60	9.75**	-5.51*	-9.09**	0.00
Prasuna x TCGS-1416	6.02*	6.67**	11.86**	0.00	-0.82	0.83
Rohini x TMV-2	-11.54**	-11.28**	-11.02**	-5.49*	-6.67*	-6.67*
Rohini x ICGV-91114	1.60	1.90	2.20	0.42	-1.64	0.00
Rohini x Dharani	-2.83	0.45	4.58	-2.81	-8.33**	0.83
Rohini x TCGS-1416	-2.89	-0.58	2.46	-5.65*	-6.83*	-6.83*
Narayani x TCGS-1416	-1.69	-1.49	-1.69	-5.53*	-7.50*	-7.50*
Narayani x ICGV-91114	1.61	1.83	1.61	-0.42	-3.28	-1.67
Narayani x TMV-2	3.94	7.98**	11.8**	-6.07*	-12.12**	-3.33
Narayani x Dharani	-2.01	0.83	3.39	-2.98	-5.00	-5.00
K-6 x Dharani	-5.93*	-5.53*	-5.93*	-5.39*	-5.79*	-5.00
K-6 x TCGS-1416	0.59	1.02	0.59	-11.11**	-11.48**	-10.00**
K-6 x ICGV-91114	0.79	4.92*	8.47**	-17.00**	-20.45**	-12.50**
K-6 x TMV-2	-3.61	-0.62	1.69	9.54**	9.09**	10.00**
Greeshma x Dharani	-2.44	-0.41	1.69	-5.53*	-7.50*	-7.50*
Greeshma x ICGV-91114	-2.44	-0.41	1.69	-10.55**	-13.11**	-11.67**
Greeshma x TCGS-1416	-11.02**	-9.6**	-4.24	-10.12**	-15.91**	-7.50*
Greeshma x TMV-2	-3.69	-3.11	1.61	8.09**	5.83*	5.83*
S.E.	0.84	0.97	0.97	1.00	1.16	1.16

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Crosses	Heterosis (%)					
	Specific leaf area (cm2 g -1) at					
	40 DAS			60 DAS		
	Relative heterosis	Heterobeltiosis	Standard heterosis	Relative heterosis	Heterobeltiosis	Standard heterosis
TAG-24 x ICGV-91114	1.55	-11.34**	18.82**	-28.93**	-41.46**	-9.57**
TAG-24 x TMV-2	52.49**	52.36**	104.54**	-17.23**	-28.33**	10.72**
TAG-24 x TCGS-1416	78.38**	50.76**	104.54**	-3.20*	-20.45**	22.9**
TAG-24 x Dharani	42.52**	40.76**	93.42**	-19.22**	-29.83**	8.41**
Prasuna x Dharani	40.66**	23.17**	63.95**	-14.54**	-31.08**	12.46**
Prasuna x ICGV-91114	23.83**	23.31**	65.53**	4.72**	-11.37**	44.64**
Prasuna x TMV-2	84.92**	56.73**	108.62**	2.43	-17.58**	34.49**
Prasuna x TCGS-1416	26.57**	24.59**	71.20**	-14.64**	-27.53**	18.26**
Rohini x TMV-2	76.15**	66.43**	87.07**	22.83**	12.23**	35.65**
Rohini x ICGV-91114	49.49**	37.33**	84.35**	19.21**	15.35**	39.42**
Rohini x Dharani	97.19**	79.75**	102.04**	28.42**	17.03**	41.45**
Rohini x TCGS-1416	31.07**	19.14**	63.72**	13.83**	10.55**	33.62**
Narayani x TCGS-1416	93.48**	88.44**	88.44**	-9.44**	-28.11**	22.32**
Narayani x ICGV-91114	42.57**	21.62**	63.27**	-2.76	-19.08**	37.68**
Narayani x TMV-2	83.05**	80.86**	71.43**	-2.37	-22.66**	31.59**
Narayani x Dharani	77.34**	49.83**	105.90**	-17.96**	-31.52**	16.52**
K-6 x Dharani	89.3**	61.54**	128.57**	12.41**	-10.48**	51.01**
K-6 x TCGS-1416	1.32	-1.28	39.68**	-25.72**	-37.97**	4.64*
K-6 x ICGV-91114	6.59	-11.86**	24.72**	-9.41**	-28.01**	21.45**
K-6 x TMV-2	27.48**	25.64**	77.78**	-26.36**	-38.32**	4.06
Greeshma x Dharani	2.21	-8.29	15.42**	-23.16**	-37.04**	-1.45
Greeshma x ICGV-91114	3.40	0.17	34.57**	-8.60**	-21.3**	23.19**
Greeshma x TCGS-1416	-7.79	-20.00**	0.68	-23.22**	-37.22**	-1.74
Greeshma x TMV-2	5.08	0.66	38.32**	-15.11**	-26.67**	14.78**
S.E.	6.75	7.79	7.79	2.33	2.69	2.69

Contd....

Crosses	Heterosis (%)					
	Specific leaf weight (g cm^{-2}) at					
	40 DAS			40 DAS		
	Relative heterosis	Heterobeltiosis	Standard heterosis	Relative heterosis	Heterobeltiosis	Standard heterosis
TAG-24 x ICGV-91114	-14.29	-14.29	-14.29	-88.89**	-88.89**	-88.89**
TAG-24 x TMV-2	-50.00*	-57.14*	-57.14*	-5.88	-11.11	-11.11
TAG-24 x TCGS-1416	-57.14**	-57.14*	-57.14*	-22.22	-22.22	-22.22
TAG-24 x Dharani	-50.00*	-57.14*	-57.14*	0.00	-11.11	-11.11
Prasuna x Dharani	-27.27	-42.86	-42.86	-5.88	-11.11	-11.11
Prasuna x ICGV-91114	-11.11	-20.00	-42.86	-25.00	-25.00	-33.33
Prasuna x TMV-2	-45.45	-57.14*	-58.14*	-29.41	-33.30	-33.33
Prasuna x TCGS-1416	-18.52	-26.67	-47.62*	-6.67	-12.50	-22.22
Rohini x TMV-2	-38.46	-42.86	-42.86	-29.41	-33.33	-33.33
Rohini x ICGV-91114	-27.27	-33.33	-42.86	-25.00	-25.00	-33.33
Rohini x Dharani	-53.85*	-57.14	-57.14*	-29.41	-33.33	-33.33
Rohini x TCGS-1416	-27.27	-33.33	-42.86	-20.00	-25.00	-33.33
Narayani x TCGS-1416	-20.00	-42.86	-42.86	-6.67	-22.22	-22.22
Narayani x ICGV-91114	0.00	-20.00	-42.86	-14.29	-25.00	-33.33
Narayani x TMV-2	-20.00	-42.86	-42.86	-6.67	-22.22	-22.22
Narayani x Dharani	-25.00	-40.00	-57.14	7.69	0.00	-22.22
K-6 x Dharani	-40.00	-58.14	-57.14*	-25.00	-33.33	-33.33
K-6 x TCGS-1416	25.00	0.09	-28.57	6.67	0.00	-11.11
K-6 x ICGV-91114	0.00	-28.57	-28.57	-12.5	-22.22	-22.22
K-6 x TMV-2	0.00	-20.00	-42.86	14.29	14.29	-11.11
Greeshma x Dharani	-16.67	-28.57	-28.57	12.50	0.00	0.00
Greeshma x ICGV-91114	0.00	0.00	-28.57	-6.67	-12.50	-22.22
Greeshma x TCGS-1416	16.67	0.00	0.00	12.50	0.00	0.00
Greeshma x TMV-2	0.00	0.00	-28.57	14.29	14.29	-11.11
S.E.	0.14	0.16	0.16	0.19	0.22	0.22

Contd....

Crosses	Heterosis (%)					
	Relative water content at					
	60 DAS			60 DAS		
	Relative heterosis	Heterobeltiosis	Standard heterosis	Relative heterosis	Heterobeltiosis	Standard heterosis
TAG-24 x ICGV-91114	1.17	0.78	1.57	-7.43**	-10.00**	-4.71*
TAG-24 x TMV-2	-1.98	-3.50*	-2.75	-9.09**	-11.11**	-5.88**
TAG-24 x TCGS-1416	-4.69**	-5.06**	-4.31**	0.96	-2.96	2.75
TAG-24 x Dharani	10.37**	9.73**	10.59**	-1.15	-4.07*	1.57
Prasuna x Dharani	-3.17*	-4.31**	-4.31**	-1.74	-3.05	-0.39
Prasuna x ICGV-91114	2.41	2.41	0.00	-7.31**	-8.02**	-5.49**
Prasuna x TMV-2	1.19	0.00	0.00	-4.5**	-6.87**	-4.31*
Prasuna x TCGS-1416	1.39	0.39	0.00	-1.55	-3.05	-0.39
Rohini x TMV-2	-3.11*	-3.86**	-2.35	-0.77	-3.00	1.57
Rohini x ICGV-91114	3.94**	1.93	3.53*	-5.52**	-7.12**	-2.75
Rohini x Dharani	-0.78	-1.54	0.00	-5.81**	-8.99**	-4.71*
Rohini x TCGS-1416	0.19	-0.77	0.78	-2.11	-4.49*	0.00
Narayani x TCGS-1416	-1.38	-1.57	-1.57	0.78	0.00	1.57
Narayani x ICGV-91114	0.60	-0.39	-0.78	-6.38**	-6.56**	-5.1**
Narayani x TMV-2	0.20	0.00	0.00	3.94*	1.93	3.53
Narayani x Dharani	-3.15*	-3.15*	-3.53*	-4.87**	-5.79**	-4.31*
K-6 x Dharani	-1.57	-1.96	-1.96	-1.93	-3.42	-0.39
K-6 x TCGS-1416	2.79*	1.98	1.18	-2.50	-3.42	-0.39
K-6 x ICGV-91114	3.15*	2.75	2.75	5.47**	2.66	5.88**
K-6 x TMV-2	-0.99	-1.18	-1.57	-5.61**	-7.22**	-4.31*
Greeshma x Dharani	2.58*	1.18	1.18	-7.45**	-7.45**	-7.45**
Greeshma x ICGV-91114	2.62*	2.41	0.00	-4.87**	-5.43**	-4.31*
Greeshma x TCGS-1416	1.39	0.00	0.00	2.78	1.57	1.57
Greeshma x TMV-2	0.80	-0.39	-0.78	-8.84**	-9.02**	-9.02**
S.E.	1.09	1.26	1.26	1.39	1.60	1.60

Crosses	Heterosis (%)					
	Root length(cm)			Dry haulm weight per plant (g)		
	Relative heterosis	Heterobeltiosis	Standard heterosis	Relative heterosis	Heterobeltiosis	Standard heterosis
TAG-24 x ICGV-91114	-0.80	-3.69	4.40	22.83**	8.33*	41.82**
TAG-24 x TMV-2	1.63	-66.87	27.20	5.36	-15.42**	10.73*
TAG-24 x TCGS-1416	0.28	4.06	12.80	-18.33**	-28.54**	24.73**
TAG-24 x Dharani	-1.12	1.48	10.00	16.67**	8.33**	65.45**
Prasuna x Dharani	1.85	34.48	40.40	56.36**	25.33**	107.82**
Prasuna x ICGV-91114	-0.32	-71.88	8.00	42.43**	5.26	74.55**
Prasuna x TMV-2	-2.37	-18.39	-14.80	54.17**	50.31**	162.36**
Prasuna x TCGS-1416	0.83	31.80	37.60	18.72**	14.04**	89.09**
Rohini x TMV-2	1.43	10.19	16.80	-29.23**	-38.67**	-16.36**
Rohini x ICGV-91114	0.73	-73.44	2.00	6.24	-16.00**	14.55**
Rohini x Dharani	0.92	0.00	6.00	8.77**	-3.13	69.09**
Rohini x TCGS-1416	-3.08	-32.08	-28.00	35.85**	28.57**	96.36**
Narayani x TCGS-1416	-0.28	4.80	4.80	60.31**	38.16**	90.91**
Narayani x ICGV-91114	-1.67	-78.75	-18.40	34.28**	5.66	46.00**
Narayani x TMV-2	-0.12	2.41	2.00	6.98**	-4.17	67.27**
Narayani x Dharani	2.07	42.97	42.40	-8.75**	-13.10**	32.73**
K-6 x Dharani	-1.10	-9.63	-2.40	-27.94**	-39.51**	-10.91*
K-6 x TCGS-1416	0.33	-71.77	8.40	34.83**	3.700	52.73**
K-6 x ICGV-91114	-0.48	-7.04	0.40	-46.89**	-51.04**	-14.55**
K-6 x TMV-2	1.25	25.19	35.20	-6.67*	-8.33**	40.00**
Greeshma x Dharani	-1.11	-5.93	1.60	78.31**	54.53**	110.73**
Greeshma x ICGV-91114	-0.71	-73.96	0.00	56.83**	24.00**	69.09**
Greeshma x TCGS-1416	1.77	21.85	31.60	-40.35**	-46.88**	-7.27
Greeshma x TMV-2	0.04	15.56	24.80	9.43**	3.57	58.18**
S.E.	5.04	5.82	5.82	0.74	0.85	0.85

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Crosses	Heterosis (%)					
	Harvest index (%)			Pod yield per plant (g)		
	Relative heterosis	Heterobeltiosis	Standard heterosis	Relative heterosis	Heterobeltiosis	Standard heterosis
TAG-24 x ICGV-91114	1.47	-5.14**	-5.14**	20.67**	13.16**	29.26**
TAG-24 x TMV-2	3.65**	-4.69**	-1.23	4.76	-11.23**	1.40
TAG-24 x TCGS-1416	13.44**	12.92**	-1.81	-2.48	-7.81**	18.24**
TAG-24 x Dharani	28.96**	23.58**	7.46**	69.57**	57.37**	79.76**
Prasuna x Dharani	-18.92**	-23.91**	-23.91**	12.33**	4.48	21.44**
Prasuna x ICGV-91114	-6.36**	-13.57**	-10.43**	42.01**	19.48**	38.88**
Prasuna x TMV-2	-23.72**	-24.38**	-33.7**	4.92	0.000	28.26**
Prasuna x TCGS-1416	22.77**	17.19**	2.75	74.53**	60.69**	86.77**
Rohini x TMV-2	-7.87**	-10.87**	-10.87**	-43.31**	-46.84**	-39.28**
Rohini x ICGV-91114	4.78**	-0.35	3.26*	24.22**	5.26	20.24**
Rohini x Dharani	-11.42**	-14.88**	-20.43**	-10.74	-15.63**	8.22**
Rohini x TCGS-1416	-8.37**	-15.12**	-20.65**	24.57**	15.61**	32.06**
Narayani x TCGS-1416	-17.00**	-23.91**	-23.91**	-48.93**	-67.32**	16.83**
Narayani x ICGV-91114	-11.01**	-19.72**	-16.81**	-53.21**	-71.41**	2.20
Narayani x TMV-2	0.90	-0.76	-14.49**	-50.91**	-66.65**	19.24**
Narayani x Dharani	-16.62**	-18.43**	-32.03**	77.73**	13.17**	104.61**
K-6 x Dharani	4.29**	-2.17	-2.17	-22.81**	-25.74**	-19.64**
K-6 x TCGS-1416	-20.42**	-26.57**	-23.91**	51.50**	31.30**	42.08**
K-6 x ICGV-91114	25.35**	24.32**	8.91**	-23.73**	-29.69**	-9.82**
K-6 x TMV-2	0.22	-4.30	-16.16**	-5.06	-9.63	-2.20
Greeshma x Dharani	4.02**	-6.16**	-6.16**	-7.39	-38.32**	85.77**
Greeshma x ICGV-91114	-29.29**	-37.2**	-34.93**	-58.82**	-73.99**	-21.64**
Greeshma x TCGS-1416	42.93**	38.18**	19.06**	-15.63**	-39.85**	81.16**
Greeshma x TMV-2	25.43**	24.86	0.43	-23.96**	-49.63**	51.70**
S.E.	0.58	0.67	0.67	0.70	0.70	0.92

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

Table 2: List of best F_1s for water use efficiency traits and yield traits in groundnut

Character	Best heterotic crosses based on		
	Relative heterosis	Heterobeltiosis	Standard heterosis
Days to 50 per cent flowering	NARAYANI X DHARANI PRASUNA X TCGS-1416 TAG-24 X TMV-2	NARAYANI X DHARANI PRASUNA X TCGS-1416 TAG-24 X TMV-2	ROHINI X TCGS-1416 NARAYANI X DHARANI
Days to maturity	K-6 X ICGV-91114 TAG-24 X TMV-2 GREESHMA X TCGS-1416	NARAYANI X TMV-2 GREESHMA X DHARANI ROHINI X DHARANI	NARAYANI X TMV-2 NARAYANI X ICGV-91114 GREESHMA X TCGS-1416
SPAD chlorophyll meter reading at 40 DAS	PRASUNA X DHARANI TAG-24 X TMV-2 PRASUNA X ICGV-91114	PRASUNA X DHARANI TAG-24 X TMV-2 NARAYANI X TMV-2	PRASUNA X DHARANI TAG-24 X TMV-2 PRASUNA X ICGV-91114 PRASUNA X TCGS-1416
SPAD chlorophyll meter reading at 60 DAS	TAG-24 X TMV-2 K-6 X TMV-2 GREESHMA X TMV-2	TAG-24 X TMV-2 K-6 X TMV-2 GREESHMA X TMV-2	TAG-24 X TMV-2 K-6 X TMV-2 GREESHMA X TMV-2
Specific leaf area (cm^2 g^{-1}) at 40 DAS	GREESHMA X TCGS-1416 K-6 X TCGS-1416 GREESHMA X DHARANI	GREESHMA X TCGS-1416 K-6 X ICGV-91114 TAG-24 X ICGV-91114	GREESHMA X TCGS-1416 GREESHMA X TCGS-1416 K-6 X ICGV-91114
Specific leaf area (cm^2 g^{-1}) at 60 DAS	TAG-24 X ICGV-91114 K-6 X TMV-2 K-6 X TCGS-1416	TAG-24 X ICGV-91114 K-6 X TMV-2 GREESHMA X TCGS-1416	TAG-24 X ICGV-91114 GREESHMA X TCGS-1416 GREESHMA X DHARANI
Specific leaf weight (g cm^{-2}) at 40 DAS	GREESHMA X TMV-2 K-6 X TMV-2 GREESHMA X DHARANI	K-6 X TCGS-1416 GREESHMA X ICGV-91114 GREESHMA X TCGS-1416 GREESHMA X TMV-2	GREESHMA X TCGS-1416
Specific leaf weight (g cm^{-2}) at 60 DAS	K-X TMV-2 GREESHMA X TMV-2 GREESHMA X DHARANI GREESHMA X TCGS-1416	GREESHMA X TMV-2 K-6 X TMV-2 GREESHMA X TCGS-1416	GREESHMA X TCGS-1416 GREESHMA X DHARANI
Relative water content (%) at 40 DAS	TAG-24 X DHARANI ROHINI X ICGV-91114 K-6 X ICGV-9114	TAG-24 X DHARANI K-6 X ICGV-9114 PRASUNA X ICGV-91114	TAG-24 X DHARANI ROHINI X ICGV-91114 K-6 X ICGV-91114
Relative water content (%) at 60 DAS	K-6 X ICGV-91114 NARAYANI X TMV-2 GREESHMA X TCGS-1416	K-6 X ICGV-91114 NARAYANI X TMV-2 GREESHMA X TCGS-1416	K-6 X ICGV-91114 TAG-24 X TCGS-1416 NARAYANI X TMV-2
Root length(cm)	NARAYANI X DHARANI PRASUNA X DHARANI GREESHMA X TCGS-1416	NARAYANI X DHARANI PRASUNA X DHARANI PRASUNA X TCGS-1416	NARAYANI X DHARANI PRASUNA X DHARANI PRASUNA X TCGS-1416
Dry haulm weight per plant (g)	GREESHMA X DHARANI NARAYANI X TCGS-1416 PRASUNA X DHARANI	GREESHMA X DHARANI PRASUNA X TMV-2 NARAYANI X TCGS-1416	PRASUNA X TMV-2 GREESHMA X DHARANI PRASUNA X DHARANI
Harvest index (%)	GREESHMA X TCGS-1416 TAG-24 X DHARANI GREESHMA X TMV-2	GREESHMA X TCGS-1416 K-6 X ICGV-91114 TAG-24 X DHARANI	GREESHMA X TCGS-1416 K-6 X ICGV-91114 TAG-24 X DHARANI
Pod yield per plant (g)	NARAYANI X DHARANI PRASUNA X TCGS-1416 TAG-24 X DHARANI		NARAYANI X DHARANI