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Identification of Heterotic Crosses for yield and Water Use Efficiency Traits in Relation to Moisture Stress Tolerance in Groundnut (*Arachis hypogaea* L.)

K. John[1*], P. Raghava Reddy[2], T. C. M. Naidu[3] and N. V. Naidu[4]

[1]Dept. of Genetics and Plant Breeding, Institute of Frontier Technology, Regional Agricultural Research Station, Tirupati, Andhra Pradesh (517 502) India

[2]Dept. Genetics and Plant Breeding, [4]Dept. of Genetics and Plant Breeding, Acharya N. G. Ranga Agricultural University, Andhra Pradesh (522 034), India

[3]Dept. of Crop Physiology, Institute of Frontier Technology, Regional Agricultural Research Station, Tirupati, Andhra Pradesh (517 502), India

Corresponding Author

K. John

e-mail: johnlekhana@rediffmail.com

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Abstract

The experimental material comprised of 24 F_1 crosses generated through Line×Tester analysis. The relative heterosis, heterobeltiosis and standard heterosis were estimated for yield and water use efficiency traits. The heterobeltiosis for SPAD chlorophyll meter reading ranged from -20.45% (K-6×ICGV-91114) to 15.25% (TAG-24×TMV-2). For specific leaf area the heterobeltiosis ranged from 41.46% (TAG-24×ICGV-91114) to 17.03% (Rohini×Dharani). The cross Prasuna×TCGS -1416 recorded the highest heterobeltiosis for number of mature pods per plant (53.33%), Rohini×ICGV-91114 for shelling per cent (8.58%), Prasuna×Dharani for sound mature kernel per cent (10.04%), TAG-24×Dharani for kernel yield plant^{-1} (90.75%) and Prasuna×TCGS-1416 for pod yield plant^{-1} (60.69%). Based on heterobeltiosis the best heterotic crosses were identified for different traits *viz.,* SPAD chlorophyll meter reading (TAG-24×TMV-2, K-6×TMV-2 and Greeshma x TMV-2), specific leaf area (TAG-24×ICGV-91114, K-6×TMV-2 and Greeshma×TCGS-1416), shelling per cent (Rohini x ICGV-91114, K-6×TCGS-1416 and TAG-24×Dharani), kernel yield plant^{-1} (TAG-24×Dharani, Greeshma×Dharani and Greeshma×TMV-2) and pod yield plant^{-1} (Prasuna×TCGS-1416, TAG-24×Dharani and Prasuna×ICGV-91114). These hybrids offer best possibilities of future exploitation for development of high yielding moisture stress tolerant groundnut genotypes.

Keywords: Heterosis, yield, water use efficiency traits, groundnut

1. Introduction

Water use efficiency is the ratio of the total drymatter produced per unit of water transpired. Variation in WUE among genotypes of same species was first documented by Briggs and Shantz (1913) and the possibility of using this as a selection trait in breeding for drought tolerant genotypes has been reported by Tanner and Sinclair (1983). Recent studies have confirmed that substantial genotypic variation for WUE exists in groundnut (Hubick et al., 1986). Wright *et al.* (1988) showed that the genotypic variability for WUE in groundnut ranged from 2.15 to 3.71 g of dry matter per kg of water used. Hebbar (1990) reported a variation from 1.57 to 2.66 g drymatter per kg of water. Wright et al. (1993) reported a genotypic variation from 1.8 to 3.7g of dry matter production per kg of water used. Genotypic differences in WUE of 4 peanut genotypes ranged from 1.81 to 3.05 g kg^{-1} under intermittent water deficit and from 2.07 to 3.15 g kg^{-1} under continuous water deficit. These studies suggest the possibility of using this trait in breeding for drought resistance.

Selection for higher WUE often resulted in decrease in crop growth rates and this was perhaps the most significant setback for further improvement in this trait. This lack of success arises primarily due to strong inter-dependency between transpiration and WUE. Therefore it is essential to identify types where this interdependency is lower. According to Udayakumar et al. (1998), two important physiological traits that determine the variability in WUE are photosynthetic rate and transpiration rate. Photosynthetic rate is regulated by intrinsic mesophyll efficiency and the CO_2 diffusive process associated with stomata. Transpiration rate is predominantly controlled by differences in mesophyll efficiency. They stated that in crops like groundnut (capacity type) WUE is independent of total transpiration and selection for WUE is likely to result in higher total drymatter production. Water use efficiency is known to increase with decrease in the quantity of water applied without substantial decrease in yield (Hammond and Boote, 1981). Nimitr Vorasoot et al. (1988) found WUE to be higher in groundnuts that received lower water regimes at longer irrigation intervals (14 days). Rosario and Fajardo (1988) reported that WUE decreased under water stress in all cultivars of groundnut. Genotypes with greater decrease in stomatal conductance and a minimum change in assimilation rate always show a greater increase in WUE under stress (Hebbar, 1990). Significant positive relation between WUE values obtained in control and stress treatments was also reported by many workers indicating that the G×E is very low for this trait (Wright et al., 1992). Even though WUE was high under stress, the genotypic ranking has been shown to remain constant under non stress and stress conditions (Udayakumar et al., 1998). Hebbar et al. (1994) showed that more than 92% of the variation in dry matter accumulation was accounted by the variation in WUE. WUE varied significantly between genotypes and there was a positive correlation between WUE and the quantity of dry matter produced by the genotypes. Babitha and Reddy (2001) reported that total drymatter produced per plant had positive correlation with WUE in simulated drought (r=0.31, $p<0.05$) and rain fed treatments (r=0.42, $p<0.05$) and water use efficient genotypes were high TDM producers with poor harvest index.

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. In groundnut, heterosis cannot be exploited for higher production through commercial hybrids due to cleistogamous nature of flower and poor seed recovery during hybridization. For the development of an effective heterosis breeding programme in groundnut, one need to have information about genetic architecture and estimated prepotency of parents in hybrid combinations (Waghmode et al., 2017). 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 yield and water use efficiency traits.

2. Materials and Methods

The experimental material comprised of twenty four F_1 single crosses generated through Line×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 Regional Agricultural Research Station, Tirupati. The F_1 hybrids were grown in plots consisting of single row of 5m length having a spacing of 30.0×10 cm^2. In parents and F_1 hybrids, twenty plants per replication per genotype per replication per cross were sampled for recording observations. Data were recorded for plant height (cm), number of primary branches $plant^{-1}$, no. of secondary branches $plant^{-1}$, SPAD Chlorophyll meter reading, specific leaf area (cm^2 g^{-1}), no. of mature pods $plant^{-1}$, shelling per cent, sound mature kernel per cent, kernel yield $plant^{-1}$ (g) and pod yield $plant^{-1}$ (g). The water use efficieny traits *viz*., SPAD chlorophyll meter reading (SCMR) was measured on all four-leaflets of third leaf from the top on main axis at 60 DAS under normal sunlight using SPAD meter of Minolta Company, NJ, USA (SPAD-502). Specific leaf area (SLA) was recorded at 60 days after sowing. Ten leaves (3rd fully expanded leaf from the top on the main axis) were collected from each treatment in each replication for calculating SLA. These leaves were cleaned and their leaf area was estimated using a leaf area meter (LICOR model-3100). They were dried in a hot air oven at 80 °C and dry weight recorded. The formula used was:

$$SLA = \frac{\text{Leaf area } (cm^2)}{\text{Leaf dry weight (g)}}$$

The overall mean values of each character for each parent and F_1 utilized and relative heterosis was calculated as the per cent deviation of mean of the F_1 from its mid parental value between two corresponding parents. Heterobeltiosis was estimated as difference between the mean of the F_1 and that of the parent with greater expression for each of the character in each F_1 combination. Standard heterosis was calculated as the per cent deviation of mean of F_1 from standard parent. 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.

$$\text{Relative heterosis (\%)} = \frac{\bar{F}_1 - \bar{M}_p}{\bar{M}_p} \times 100$$

$$\text{Heterobeltiosis (\%)} = \frac{\bar{F}_1 - \bar{B}_p}{\bar{B}_p} \times 100$$

$$\text{Standard heterosis (\%)} = \frac{\bar{F}_1 - \bar{S}_p}{\bar{S}_p} \times 100$$

3. 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.

3.1. Plant height (cm)

Relative heterosis for plant height ranged from -31.13% (TAG-24×TMV-2) to 20.77% (TAG-24×Dharani). Two F_1s exhibited positive significant relative heterosis. Significant negative heterosis over mid-parent was observed in eight F_1s. The minimum and maximum heterosis for plant height over better parent was observed in F_1s TAG-24×TMV-2 (-38.20%) and TAG-24×Dharani (20.59%) respectively. Thirteen F_1s exhibited significant negative heterosis over better parent and only one F_1exhibited positive significant heterosis over better parent. Standard heterosis ranged from –36.72% (TAG-24×TMV-2) to 18.40% (Narayani×Dharani). Significant and negative heterosis over standard parent was observed in seven F_1s.

3.1.2. No. of primary branches plant^{-1}

The range of heterosis over mid parent varied from -20.00% (TAG-24×Dharani) to 74.17% (Greeshma×Dharani). Significant positive heterosis was observed in six F_1s only, while significant negative heterosis was noticed in eight F_1s. Heterobeltiosis for number of primary branches plant^{-1} ranged from –20.00% (seven F_1s) to 74.17% (Greeshma×Dharani). Among twenty four F_1s studied, six F_1s exhibited significant positive heterosis over better parent. Negative and significant heterosis was noticed in seven F_1s over better parent. Standard heterosis ranged from –0.00% (Sixteen F_1s) to 74.17% (Greeshma×Dharani). Significant and positive heterosis over standard parent was observed in eight F_1s.

3.1.3. No. of secondary branches plant^{-1}

The range of heterosis over mid-parent varied from 93.33% (TAG-24×Dharani) to 1900.00% (Narayani×ICGV-91114 and K-6×ICGV-91114). Out of twenty four F_1s, eighteen F_1s recorded significant positive heterosis over mid-parent and non significant positive heterosis was noticed in two F_1s. Significant negative heterosis was noticed in four F_1s. Heterobeltiosis ranged from -95.00% (TAG-24×Dharani) to 1900.00% (Narayani×ICGV-91114 and K-6×ICGV-91114). Significant and positive heterosis was observed in ten F_1s. Significant negative heterosis was noticed in four F_1s. Standard heterosis ranged from -90.00% (Four F_1s) to 300.00% (Prasuna×TCGS-1416). Out of twenty four F_1s, eight F_1s recorded significant positive heterosis over standard parent.

3.1.4. SPAD chlorophyll meter reading

The range of heterosis over mid parent varied from 17.00% (K-6×ICGV-91114) to 15.25% (TAG-24×TMV-2). Significant positive heterosis was observed in three F1s 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×ICGV-91114) to 15.25% (TAG-24×TMV-2). Among twenty four F1s studied, three F1s exhibited significant positive heterosis over better parent. Thirteen F1s 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 F1s. Standard heterosis ranged from -12.50% (K-6×ICGV-91114) to 15.25% (TAG-24×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 F1s. These results are in agreement with the results of Seethala Devi (2004).

3.1.5. Specific leaf area (cm^2 g^{-1})

The range of heterosis over mid-parent varied from -28.93% (TAG-24×ICGV-91114) to 28.42% (Rohini×Dharani). Out of twenty four F1s, six F1s recorded significant positive heterosis over mid-parent. Significant negative heterosis was noticed in fifteen F_1s. Heterobeltiosis ranged from 41.46% (TAG-24×ICGV-91114) to 17.03% (Rohini×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×ICGV-91114) to 97.19% (Rohini× Dharani). Out of twenty four F1s, twenty F1s 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); Pallas (1982).

3.1.6. No. of mature pods plant^{-1}

The range of heterosis over mid-parent varied from -16.67% (Narayani×Dharani) to 78.27% (Prasuna×TCGS-1416). Out of twenty four F_1s, thirteen F_1s recorded significant positive heterosis over mid-parent. Significant negative heterosis was noticed in four F_1s. Heterobeltiosis ranged from 22.62% (Narayani×Dharani) to 53.33% (Prasuna×TCGS-1416). Significant and positive heterosis was observed in twelve F_1s. Significant negative heterosis was noticed in eight F_1s. Standard heterosis ranged from 1.33% (Rohini×TMV-2) to 114.67% (Prasuna×TCGS-1416). Out of twenty four F_1s, twenty two F_1s recorded significant positive heterosis over standard parent and non significant positive heterosis was noticed in only two F_1s. Similar results were reported by John et al. (2012).

3.1.7. Shelling per cent

The relative heterosis for shelling per cent varied from -12.36% (Prasuna×TCGS-1416) to 9.33% (Rohini×ICGV-91114). Eight F_1s registered significant positive heterosis and eight F_1s showed significant negative heterosis over mid parent. Heterobeltiosis ranged from -12.56% (Prasuna×TCGS-1416)

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

Crosses	Heterosis (%)											
	Plant height (cm)			No. of primary branches plant^{-1}			SPAD chlorophyll meter reading			Specific leaf area (cm^2 g^{-1})		
	>MP	>BP	>SP	>MP	>BP	>SP	>MP	>BP	>SP	>MP	>BP	>SP
TAG-24×ICGV-91114	-11.16	-19.44**	-19.44**	-11.11**	-20.00**	0.00	1.07	0.25	1.92	-28.93**	-41.46**	-9.57**
TAG-24×TMV-2	-31.13**	-38.2**	-36.72**	11.11**	0.00	25.00**	15.25**	15.25**	17.17**	-17.23**	-28.33**	10.72**
TAG-24×TCGS-1416	-5.41	-16.54*	-11.20	-11.11**	-20.00**	0.00	-11.02**	-14.39**	-5.83*	-3.20*	-20.45**	22.9**
TAG-24×Dharani	20.77**	20.59*	-1.60	-20.00**	-20.00**	0.00	0.41	-0.41	1.25	-19.22**	-29.83**	8.41**
Prasuna×Dharani	9.27	5.260	13.60	0.00	0.00	0.00	0.83	0.00	1.67	-14.54**	-31.08**	12.46**
Prasuna× ICGV-91114	-4.15	-6.60	0.80	25.00**	25.00**	25.00**	-4.10	-4.10	-2.50	4.72**	-11.37**	44.64**
Prasuna×TMV-2	-9.74	-10.38	-3.28	0.00	0.00	0.00	-5.51*	-9.09**	0.00	2.43	-17.58**	34.49**
Prasuna× TCGS-1416	-8.91	-20.01**	-13.68	11.11**	0.00	25.00**	0.00	-0.82	0.83	-14.64**	-27.53**	18.26**
Rohini× TMV-2	-19.13**	-25.60**	-25.60**	0.00	0.00	0.00	-5.49*	-6.67*	-6.67*	22.83**	12.23**	35.65**
Rohini× ICGV-91114	3.78	-5.55	-3.28	0.00	0.00	0.00	0.42	-1.64	0.00	19.21**	15.35**	39.42**
Rohini× Dharani	-29.5**	-36.92**	-32.88**	0.00	0.00	0.00	-2.81	-8.33**	0.83	28.42**	17.03**	41.45**
Rohini× TCGS-1416	10.14	8.57	-8.80	-11.11**	-20.00**	0.00	-5.65*	-6.83*	-6.83*	13.83**	10.55**	33.62**
Narayani× TCGS-1416	1.92	-5.35	10.40	0.00	0.00	0.00	-5.53*	-7.50*	-7.50*	-9.44**	-28.11**	22.32**
Narayani× ICGV-91114	-8.69	-14.27*	0.00	0.00	0.00	0.00	-0.42	-3.28	-1.67	-2.76	-19.08**	37.68**
Narayani×TMV-2	-13.7*	-17.49**	-3.76	0.00	0.00	0.00	-6.07*	-12.12**	-3.33	-2.37	-22.66**	31.59**
Narayani×Dharani	19.45**	1.51	18.40*	-11.11**	-20.00**	0.00	-2.98	-5.00	-5.00	-17.96**	-31.52**	16.52**
K-6 x Dharani	-14.61*	-19.72**	-8.80	0.00	0.00	0.00	-5.39*	-5.79*	-5.00	12.41**	-10.48**	51.01**
K-6×TCGS-1416	-8.15	-12.68*	-0.80	25.00**	25.00**	25.00**	-11.11**	-11.48**	-10.00**	-25.72**	-37.97**	4.64*
K-6×ICGV-91114	-25.89**	-28.24**	-18.48*	25.00**	25.00**	25.00**	-17.00**	-20.45**	-12.50**	-9.41**	-28.01**	21.45**
K-6×TMV-2	8.36	-6.90	5.76	-11.11**	-20.00**	0.00	9.54**	9.09**	10.00**	-26.36**	-38.32**	4.06
Greeshma× Dharani	9.33	7.36	7.36	74.17**	74.17**	74.17**	-5.53*	-7.50*	-7.50*	-23.16**	-37.04**	-1.45
Greeshma× ICGV-91114	-25.15**	-27.34**	-25.60**	50.00**	50.00**	50.00**	-10.55**	-13.11**	-11.67**	-8.60**	-21.3**	23.19**
Greeshma× TCGS-1416	-24.26**	-27.82**	-23.20**	50.00**	50.00**	50.00**	-10.12**	-15.91**	-7.50*	-23.22**	-37.22**	-1.74
Greeshma× TMV-2	7.42	-0.83	-4.40	-11.11**	-20.00**	0.00	8.09**	5.83*	5.83*	-15.11**	-26.67**	14.78**
SEm±	2.57	2.96	2.96	0.02	0.02	0.02	1.00	1.16	1.16	2.33	2.69	2.69

Continue...

Crosses	Heterosis (%)					
	No. of secondary branches plant^{-1}			No. of mature pods plant^{-1}		
	>MP	>BP	>SP	>MP	>BP	>SP
TAG-24×ICGV-91114	33.33**	0.00	100.00**	45.31**	36.76**	55.00**
TAG-24×TMV-2	90.48**	0.00	100.00**	18.78**	14.41**	29.67**
TAG-24×TCGS-1416	90.48**	0.00	100.00**	25.87**	20.00**	50.00**
TAG-24×Dharani	-93.33**	-95.00**	-90.00**	46.05**	32.14**	85.00**
Prasuna×Dharani	0.00	0.00	0.00	13.86**	13.39**	14.33**
Prasuna×ICGV-91114	93.94**	6.67**	6.67**	27.13**	24.6**	30.83**
Prasuna×TMV-2	263.64**	100.00**	100.00**	23.99**	12.00**	40.00**
Prasuna× TCGS-1416	300.00**	300.00**	300.00**	78.27**	53.33**	114.67**
Rohini×TMV-2	-90.00**	-90.00**	-90.00**	3.14	1.33	1.33
Rohini×ICGV-91114	-81.82**	-90.00**	90.00**	26.88**	21.75**	27.83**
Rohini× Dharani	81.82**	0.00	0.00	32.13**	17.07**	46.33**
Rohini× TCGS-1416	-90.00**	-90.00**	-90.00**	2.75	-13.21**	21.50**
Narayani×TCGS-1416	263.64**	100.00**	100.00**	4.55	-4.17	15.00**
Narayani×ICGV-91114	1900.00**	1900.00**	100.00**	-2.22	-8.33**	10.00**
Narayani×TMV-2	900.00**	900.00**	0.00	20.82**	18.40**	48.00**
Narayani×Dharani	81.82**	0.00	0.00	-16.67**	-22.62**	8.33*
K-6 x Dharani	81.82**	0.00	0.00	-2.27	-12.71**	11.00**
K-6×TCGS-1416	900.00**	900.00**	0.00	1.08	-7.73**	17.33**
K-6×ICGV-91114	1900**	1900.00**	100**	-11.96**	-12.71**	11.00**
K-6×TMV-2	81.82**	0.00	0.00	-10.17**	-14.29**	20.00**
Greeshma×Dharani	81.82**	0.00	0.00	46.82**	34.58**	61.50**
Greeshma×ICGV-91114	900.00**	900.00**	0.00	-5.33*	-11.25**	6.50
Greeshma×TCGS-1416	0.00	0.00	-90.00**	2.86	0.80	26.00**
Greeshma×TMV-2	263.64**	100.00**	100**	11.92**	3.93	45.50**
SEm±	0.01	0.02	0.02	0.61	0.70	0.70

Table 1 Continue...

Crosses	Heterosis (%)					
	Shelling per cent			Sound mature kernel per cent		
	>MP	>BP	>SP	>MP	>BP	>SP
TAG-24×ICGV-91114	3.93**	0.90	0.900	5.01**	3.66**	6.39**
TAG-24×TMV-2	0.21	0.00	-5.43**	3.61**	0.00	2.63**
TAG-24×TCGS-1416	1.41	0.00	-3.14**	2.78**	2.20*	4.89**
TAG-24×Dharani	6.02**	3.15**	2.69**	4.97**	4.40**	7.14**
Prasuna×Dharani	-5.83**	-5.83**	-5.83**	10.65**	10.04**	11.28**
Prasuna×ICGV-91114	-3.66**	-6.28**	-6.28**	0.96	-1.86*	-0.75
Prasuna×TMV-2	-1.14	-2.69**	-2.69**	-4.25**	-4.41**	-3.01**
Prasuna×TCGS-1416	-12.36**	-12.56**	-12.56**	-2.04*	-2.22*	-0.75
Rohini×TMV-2	3.02**	-0.45	-0.45	5.90**	3.99**	7.89**
Rohini×ICGV-91114	9.33**	8.58**	2.69**	7.55**	3.26**	7.14**

Continue...

Crosses	Heterosis (%)					
	Shelling per cent			Sound mature kernel per cent		
	>MP	>BP	>SP	>MP	>BP	>SP
Rohini×Dharani	2.22**	0.32	-2.83**	-0.35	-1.45	2.26*
Rohini×TCGS-1416	-4.65**	-7.66**	-8.07**	-1.83*	-2.90**	0.75
Narayani×TCGS-1416	-10.75**	-12.15**	-12.15**	-9.70**	-10.37**	-9.02**
Narayani×ICGV-91114	-1.38	-2.50**	-5.61**	4.20**	1.11	2.63**
Narayani×TMV-2	2.78**	2.78**	-0.45	4.46**	4.44**	6.02**
Narayani×Dharani	-9.41**	-10.63**	-11.03**	-2.22**	-2.22*	-0.75
K-6×Dharani	3.71**	0.90	0.90	2.36**	-1.05	6.02**
K-6×TCGS-1416	5.26**	5.26**	-0.45	3.53**	-2.11*	4.89**
K-6×ICGV-91114	1.19	0.00	-3.14**	2.00*	-0.7	6.39**
K-6×TMV-2	0.25	-2.25**	-2.69**	-0.18	-2.81**	4.14**
Greeshma×Dharani	0.69	-1.35	-1.35	0.19	0.00	0.38
Greeshma× ICGV-91114	-2.09**	-2.8**	-6.73**	4.41**	1.87*	2.26*
Greeshma×TCGS-1416	-6.05**	-6.48**	-9.42**	2.44**	1.89*	3.38**
Greeshma×TMV-2	0.46	-1.35	-1.79*	3.54**	2.96**	4.51**
SEm±	0.53	0.61	0.61	0.73	0.84	0.84

Table 1 Continue...

Crosses	Heterosis (%)					
	Kernel yield plant^{-1} (g)			Pod yield plant^{-1} (g)		
	>MP	>BP	>SP	>MP	>BP	>SP
TAG-24×ICGV-91114	26.8**	18.3**	18.30**	20.67	13.16	29.26
TAG-24×TMV-2	16.61**	6.55	-7.73*	4.76	-11.23	1.40
TAG-24×TCGS-1416	5.01	-9.30**	7.99*	-2.48	-7.81	18.24
TAG-24×Dharani	93.55**	90.75**	70.10**	69.57	57.37	79.76
Prasuna×Dharani	0.72	-6.03*	8.51*	12.33	4.48	21.44
Prasuna× ICGV-91114	29.48**	4.91	21.13**	42.01	19.48	38.88
Prasuna×TMV-2	0.88	-0.65	18.30**	4.92	0.000	28.26
Prasuna×TCGS-1416	57.43**	39.51**	61.08**	74.53	60.69	86.77
Rohini×TMV-2	-41.92**	-43.07**	-40.72**	-43.31	-46.84	-39.28
Rohini×ICGV-91114	24.63**	5.20	9.54**	24.22	5.26	20.24
Rohini× Dharani	-12.24**	-17.75**	-2.06	-10.74	-15.63	8.22
Rohini× TCGS-1416	16.80**	8.42*	12.89**	24.57	15.61	32.06
Narayani×TCGS-1416	5.74	-0.26	-0.26	-48.93	-67.32**	16.83
Narayani× ICGV-91114	14.15**	3.20	-8.51*	-53.21	-71.41**	2.20
Narayani×TMV-2	12.16**	-2.16	16.49**	-50.91	-66.65**	19.24
Narayani×Dharani	1.16	0.87	-10.05**	77.73**	13.17	304.61**
K-6 x Dharani	-23.82**	-25.00**	-25.00**	-22.81	-25.74	-19.64
K-6×TCGS-1416	65.14**	43.6**	39.18**	51.50	31.30	42.08
K-6×ICGV-91114	-22.43**	-29.65**	-16.24**	-23.73	-29.69	-9.82
K-6×TMV-2	-3.60	-7.45*	-10.31**	-5.06	-9.63	-2.20

Continue...

Crosses	Heterosis (%)					
	Kernel yield plant^{-1} (g)			Pod yield plant^{-1} (g)		
	>MP	>BP	>SP	>MP	>BP	>SP
Greeshma×Dharani	80.91**	68.56**	68.56**	-7.39	-38.32	85.77
Greeshma×ICGV-91114	-10.93**	-18.51**	-29.64**	-58.82	-73.99	-21.64
Greeshma×TCGS-1416	1.13	-12.77**	3.87	-15.63	-39.85	81.16
Greeshma×TMV-2	67.99**	65.32**	47.42**	-23.96	-49.63	51.70
SEm±	0.38	0.43	0.43	10.59	12.23	12.23

*Significant at (p=0.05) level; **Significant at (p=0.01) level ; MP: Mid parent; BP: Better parent; SP: Standard parent

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

Character	Best heterotic crosses-based on		
	Relative heterosis	Heterobeltiosis	Standard heterosis
Plant height (cm)	TAG-24×TMV-2 Rohini×Dharani K-6×ICGV-91114	TAG-24×TMV-2 Rohini×Dharani K-6×ICGV-91114	TAG-24×TMV-2 Rohini×Dharani Rohini×TMV-2
No. of primary branches plant^{-1}	Greeshma×Dharani Greeshma×ICGV-91114 Greeshma×TCGS-1416	Greeshma×Dharani Greeshma×ICGV-91114 Greeshma×TCGS-1416	Greeshma×Dharani Greeshma×ICGV-91114 Greeshma×TCGS-1416
No. of secondary branches plant^{-1}	Narayani×ICGV-91114 K-6×ICGV-91114 Narayani×TMV-2 K-6×Dharani	Narayani×ICGV-91114 K-6×ICGV-91114 Narayani×TMV-2 K-6×Dharani	Prasuna×TCGS-1416
SPAD chlorophyll meter reading	TAG-24×TMV-2 K-6×TMV-2 Greeshma×TMV-2	TAG-24×TMV-2 K-6×TMV-2 Greeshma×TMV-2	TAG-24×TMV-2 K-6×TMV-2 Greeshma×TMV-2
Specific leaf area (cm^2 g^{-1})	TAG-24×ICGV-91114 K-6×TMV-2 K-6 xTCGS-1416	TAG-24×ICGV-91114 K-6×TMV-2 Greeshma×TCGS-1416	TAG-24×ICGV-91114 Greeshma×TCGS-1416 Greeshma×DharanI
No. of mature pods plant^{-1}	Prasuna×TCGS-1416 TAG-24×Dharani Greeshma×Dharani	Prasuna×TCGS-1416 TAG-24×ICGV-91114 Greeshma×Dharani	Prasuna×TCGS-1416 TAG-24×Dharani Greeshma×Dharani
Shelling per cent	Rohini×ICGV-91114 K-6×TCGS-1416 TAG-24×ICGV-91114	Rohini×ICGV-91114 K-6×TCGS-1416 TAG-24×Dharani	Rohini×ICGV-91114 TAG-24×Dharani TAG-24×ICGV-91114
Sound mature kernel per cent	Prasuna×Dharani Rohini×ICGV-91114 Rohini×TMV-2	Prasuna×Dharani Narayani×TMV-2 TAG-24×Dharani	Prasuna×Dharani Rohini×TMV-2 Rohini×ICGV-91114 TAG-24×Dharani
Kernel yield plant^{-1} (g)	TAG-24×Dharani Greeshma×Dharani Greeshma×TMV-2	TAG-24×Dharani Greeshma×Dharani Greeshma×TMV-2	TAG-24×Dharani Greeshma×Dharani Prasuna×TCGS-1416
Pod yield plant^{-1} (g)	Narayani×Dharani Prasuna×TCGS-1416 TAG-24×Dharani	Prasuna×TCGS-1416 TAG-24×Dharani Prasuna×ICGV-91114	Narayani×Dharani Prasuna×TCGS-1416 Greeshma×Dharani

to 8.58% (Rohini×ICGV-91114). Four F_1s recorded significant positive heterosis and twelve F_1s recorded significant negative heterosis over better parent. Standard heterosis ranged from -12.56% (Prasuna×TCGS-1416) to 2.69% (TAG-24×Dharani). Only two F_1s recorded significant positive heterosis and seventeen F_1s recorded significant negative heterosis over

standard parent. These results were confirmed with findings of John et al. (2012), John and Raghava Reddy (2015) and Waghmode et al. (2017).

3.1.8. Sound mature kernel per cent

The relative heterosis for sound mature kernel per cent varied from -9.70% (Narayani×TCGS-1416) to 10.65% (Prasuna×Dharani). Fifteen F_1s registered significant positive heterosis and four F_1s showed significant negative heterosis over mid parent. Heterobeltiosis ranged from -10.37% (Narayani×TCGS-1416) to 10.04% (Prasuna×Dharani). Ten F_1s recorded significant positive heterosis and eight F_1s recorded significant negative heterosis over better parent. Standard heterosis ranged from -9.02% (Narayani×TCGS-1416) to 11.28% (Prasuna×Dharani). Seventeen F_1s recorded significant positive heterosis and only two F_1s recorded significant negative heterosis over standard parent.

3.1.9. Kernel yield plant^{-1} (g)

The range of heterosis over mid-parent varied from -41.92% (Rohini×TMV-2) to 93.55% (TAG-24×Dharani). Out of twenty four F_1s, twelve F_1s recorded significant positive heterosis and five F_1s showed significant negative heterosis over mid-parent. Heterobeltiosis ranged from -43.07% (Rohini×TMV-2) to 90.75% (TAG-24×Dharani). Significant and positive heterosis was observed in seven F_1s. Significant negative heterosis was noticed in nine F_1s. Standard heterosis ranged from -40.72% (Rohini×TMV-2) to 70.10% (TAG-24×Dharani). Out of twenty four F_1s, twelve F_1s recorded significant positive heterosis and non significant positive heterosis was noticed in eight F_1s over standard parent. Similar results were reported by John et al. (2012), John et al. (2014), and John and Raghava Reddy (2015).

3.1.10. Pod yield plant^{-1} (g)

Relative heterosis ranged from -50.91% (Narayani×TMV-2) to 77.73% (Narayani×Dharani). Only one F_1 recorded significant positive heterosis over mid parent. Heterobeltiosis ranged from -66.65% (Narayani×TMV-2) to 60.69% (Prasuna×TCGS-1416). Three F_1s registered significant negative heterobeltiosis. Standard heterosis ranged from -39.28% (Rohini×TMV-2) to 304.61% (Narayani×Dharani). Only one F_1 recorded significant heterosis over standard parent. Heterosis for pod yield in groundnut was also reported by 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), Jivani et al. (2009), John et al. (2012), John et al. (2014); John and Raghava Reddy (2015).

4. Conclusion

The crosses, TAG-24×TMV-2 and Prasuna×Dharani had recorded with high relative heterosis, beter parent heterosis and standard parent heterosis for SPAD chlorophyll meter reading and sound mature kernel per cent, TAG-24×ICGV-9114 with low relative heterosis, better parent heterosis and standard parent heterosis for specific leaf area, and Narayani×Dharani with high relative heterosis and standard parent heterosis for pod yield plant^{-1}. These hybrids offer best possibilities of future exploitation for development of high yielding moisture stress tolerant genotypes.

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