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DIALLEL ANALYSIS FOR YIELD, YIELD TRAITS AND FOLIAR DISEASE RESISTANCE TRAITS IN GROUNDNUT [*ARACHIS HYPOGAEA* (L.)]

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ABSTRACT

Combining ability of eight diverse genotypes for yield and foliar disease resistance traits was estimated to assess the type of gene action governing the yield and disease resistance traits and to identify genotypes suitable for use as parents in breeding for high yielding associated with foliar disease resistance. Twenty-eight F_1s (excluding reciprocals) from an eight parental diallel cross and their parents were evaluated in a randomized block design. Data were recorded on sixteen traits including morphological, yield and yield traits and foliar disease resistance traits. Highly significant GCA and SCA effects recorded for almost all the studied traits, but the SCA effects were lesser than the GCA effects indicated the additive type of gene action suggested that the selection for high yield and for foliar disease resistance should be effective in early generations. Strong association between parental means and GCA effects for yield and disease resistance traits suggested that the *per se* performance of the parental line could be used as a predictor of the capability of a line to transmit the foliar disease resistance and yielding traits to its progenies. The parental lines, GPBD 4 and ICG (FDRS) 79 were found to be suitable as good donors in a foliar disease resistance breeding program.

Key words: General combining ability, Groundnut, Specific combining ability.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is an important oilseed crop cultivated in 4.9 million ha with 5.8 million tonnes production and 1179.4 kg/ha productivity (FAOSTAT, 2012) in our country. Nearly 83% of the total area is under rainy-season. In Andhra Pradesh, it is cultivated in 10.5 lakh ha as rain-fed crop during rainy season and approximately in 2 lakh ha as irrigated crop during post-rainy season (AGROPEDIA, 2013). Groundnut yield is mainly constrained due to several abiotic and biotic stresses during the crop period.

Among biotic stresses, late leaf spot (LLS) (*Phaeoisariopsis personata* [(Berk. and Curt.) Deighton]) and rust (*Puccinia arachidicola* Speg.) are the two most economically important foliar diseases of groundnut causing severe damage to the crop (McDonald *et al.* 1985). These can cause total defoliation and reduce pod and fodder yields to an extent of over 50% and affect adversely quality of its produce (Waliyar and McDonald, 1988). Chemical control measures are available but they increase production costs by 10% (Coffelt and Porter 1986) and are beyond the reach of small and marginal farmers, who are the major producers of this crop. Therefore, development and adoption of resistant cultivars is the best option as it minimizes losses at farm level and maintains good product quality.

The diallel mating design is an efficient tool employed to identify genotypes with combining ability in desirable direction which in turn indicates general worth of a genotype to perform in combination with other genotypes in producing good offspring in segregating generations. The knowledge on combining ability and type of gene action responsible for the regulation of expression of different traits helps in planning appropriate breeding strategies. In present study, combining ability was studied for yield, yield attributes and foliar disease resistance traits to find out good general combiners to be used as donor parents for improvement of these

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traits and also to identify the specific cross combinations and to arrive at the breeding strategies for the improvement of yield and foliar disease resistance traits.

MATERIALS AND METHODS

Eight genotypes (Table 1) consisting of six released varieties (Tirupati 1, Narayani, Abhaya, Kadiri 6, TLG 45 and GPBD 4) and two advanced breeding lines (TCGS 876 and ICG (FDRS) 79) were used as parents and twenty-eight crosses were effected in 8 × 8 half diallel mating design (excluding reciprocals) during rainy season in 2009. Twenty eight F_1s and eight parents were grown in randomised block design with three replications during post-rainy season of 2009. Each F_1 was raised in a single row of 3m length while each parent was raised in 3 rows of 3m length with a spacing of 22.5 × 10cm. Data were collected on 10 randomly chosen plants in each plot in parents and F_1s for sixteen traits *viz.*, days to 50% flowering, days to maturity, plant height at harvest (cm), number of primary branches per plant, number of secondary branches per plant, number of leaves per plant, percentage of leaves affected by foliar diseases(is proportion of leaves at harvest and leaves at 85 days after sowing expressedin %), number of mature pods per plant, number of immature pods per plant, sound mature kernel percentage (SMK%), kernel yield per plant (g), shelling out-turn (%), late leaf spot severity, rust severity, harvest index (%) and pod yield per plant (g). Disease severity for LLS and rust was estimated on plant basis and scoring was done as per 1-9 point field scale at the time of harvest and the disease score was transformed into percentages using arc-sine transformation (Subrahmanyam *et al* 1982 and Subrahmanyam *et al.*1995) and then

TABLE 1: Important characteristic features of parental genotypes

Genotype	Pedigree	Botanical type / Variety	Origin	Other salient features
Tirupati 1	A selection from EC 106983/3A	Spanish bunch	Tirupati	Tolerates moisture stress conditions, waxy leaf surface, pods with slight constriction, slight beak and moderate reticulation. Susceptible to rust and LLS.
Narayani	JL 24 × Ah 316/S	Spanish bunch	Tirupati	Pods medium bold, slightly reticulated with moderate to deep constriction and slight beak. Susceptible to rust and LLS.
TPT 25	K 134 × TAG 24	Spanish bunch	Tirupati	Short statured variety, high water use efficient, tolerant to drought, moderately tolerant to foliar diseases *i.e.*, rust and LLS, pods are mostly three seeded, slender and medium bold with shallow constriction and moderate reticulation.
Kadiri 6	JL 24 × Ah 316/S	Spanish bunch	Kadiri	Pods medium bold with moderate reticulation, moderate to deep constriction and slight beak. Susceptible to rust and LLS.
TLG 45	TG 19 × TAG 24	Spanish bunch	BARC	Two seeded pods with medium constriction, medium reticulation and moderately prominent beak. Moderately resistant to foliar diseases *i.e.*, rust and LLS.
TCGS 876	TCGS 6 × TCGS 647	Virginia bunch	Tirupati	Pods medium bold, possesses high water use efficiency and resistance to PBND/PSND and sucking insects. Moderately tolerant to foliar diseases *i.e.*, rust and LLS.
GPBD 4	KRG 1 × CS 16	Spanish bunch	Dharwad	Pods medium bold, slight reticulation, slight beak with moderate constriction and resistant to foliar diseases *i.e.*, rust and LLS.
ICG(FDRS) 79	(ICGV 92069 × ICGV 93184) × (ICGV 96246 × 92R/75)	Spanish bunch	ICRISAT	Pods medium bold, medium reticulation with moderate constriction and have slight beak, resistant to foliar diseases *i.e.*, rust and LLS.

the transformed data was subjected to statistical analysis. To have uniform inoculum load, spore suspension (50,000 spores /ml) was sprayed at 80 DAS & 90 DAS in evening hours.

Analysis of variance for each character for parents and F_1s were carried out as per the method suggested by Sukhatme and Amble (1985). The significance of treatment differences was tested at five and one per cent levels of probability as per the 'F'table values (Fisher and Yates, 1963). The general combining ability (*gca*) of the parents and specific combining ability of (*sca*) of the crosses were computed by adopting method II (involves parents and F_1s only) and model I (fixed effect) of Griffing (1956).

RESULTS AND DISCUSSION

Analysis of variance revealed (Table 2) significance differences among parents and cross combinations for all the studied traits indicating the presence of substantial genetic variability. Mean squares due to GCA were found highly significant for all the traits except SMK% indicating the role of additive gene action in the control of these traits (Table 3). Mean squares due to SCA were found significant for all the traits except number of mature pods per plant, kernel yield per plant and SMK % revealing the importance of both additive and non-additive gene actions in the control of these traits. The estimates of genetic components indicated that variance due GCA was slightly low in magnitude compared to variance due to SCA for all the traits except LLS severity indicating the predominant role of non-additive gene action in line with previous reports (Garet, 1976; Vindhiyavarman, 2000; Vindhiyavarman, 2001; Hariprasanna *et al.* 2008). The additive portion of genetic variance was almost twice to that of dominance variance for LLS severity demonstrating predominance of additive gene action for this trait (Kornegay *et al.* 1980). Except for LLS severity, dominance variance was four to five times to that of additive variance indicating the importance of non-additive gene action in the expression of these traits. In the study all the traits, except LLS severity were found to be governed by non-additive gene action revealing the importance of dominance variance in the expression of most of the traits & hence the selection in early segregating generations would be in-effective.

General combining ability effects: The term, general combining ability is used to designate the average performance of a line in hybrid combination (Griffing, 1956). Study of GCA effects in combination with *per se* performance of parents will be effective to predict good general combiners for each trait. In present study, the parents, Tirupati 1, Narayani and TLG 45 were identified as early parents as they recorded significant negative GCA for days to 50 % flowering (Table 4). These three parents along with Kadiri 6 were best combiners for early maturity as they recorded significant negative GCA along with lower mean for days to maturity. TLG 45 was identified as best combiner for plant

TABLE 2: Analysis of variance (Mean squares) for 16 characters among 8 parents and 28 F_1s

Character	Replications df = 2	Treatments df = 35	Error df = 70
Days to 50% flowering	0.01	4.54**	0.31
Days to maturity	0.11	19.45**	1.01
Plant height at harvest (cm)	10.73	43.58**	9.09
Number of primary branches per plant	0.03	3.46**	0.55
Number of secondary branches per plant	0.78	1.63**	0.21
Number of leaves per plant	60.18	172.88**	48.26
Percentage of leaves affected by foliar diseases	19.18	304.41**	8.08
Number of mature pods per plant	8.53	17.80**	8.47
Number of immature pods per plant	3.08	3.76**	1.03
Kernel yield per plant (g)	3.42	6.59	4.26
Sound Mature Kernel percentage	62.36	37.92	26.82
Shelling out-turn (%)	72.12	68.21**	25.36
Late leaf spot severity	0.27	24.08**	1.51
Rust severity	0.32	26.17**	1.09
Harvest Index (%)	38.86	150.48**	16.39
Pod yield per plant (g)	18.56	17.74**	5.26

* & * * Significant at 5% and 1 % level of probability respectively

TABLE 3: Combining ability analysis of variance for yield, yield attributes and LLS and rust resistance traits in groundnut

	GCA	SCA	Error	Variance (GCA)	Variance (SCA)	Variance (gca/ sca) ratio	Additive variance (σ^2_A)	Dominance variance (σ^2_D)
	df = 7	df = 28	df = 70					
DF	3.88**	0.92**	0.1	0.01	0.11	0.09	0.02	0.11
DM	29.49**	0.73**	0.34	0.04	0.34	0.12	0.08	0.34
PH	50.88**	5.44*	3.03	0.33	3.08	0.11	0.66	3.08
PB	4.07**	0.42**	0.18	0.02	0.19	0.11	0.04	0.19
SB	0.41**	0.57**	0.07	0.01	0.07	0.14	0.02	0.07
NL	127.91**	40.05**	16.09	1.74	16.39	0.11	3.48	16.39
LAFD%	427.29**	20.01**	2.69	0.29	2.07	0.14	0.58	2.07
MP	14.75**	3.73	2.82	0.31	2.88	0.11	0.62	2.88
IMP	1.63**	1.16**	0.34	0.04	0.35	0.11	0.08	0.35
KY	3.91*	1.77	1.42	0.15	1.45	0.1	0.3	1.45
SMK%	17.52	11.42	8.94	0.97	9.11	0.11	1.94	9.11
SO	26.07**	21.91**	8.45	0.92	8.61	0.11	1.84	8.61
LLSS	30.65**	2.37**	0.5	0.55	0.51	1.08	1.1	0.51
RS	35.19**	2.11**	0.36	0.03	0.37	0.08	0.06	0.37
HI	18.76**	58.01**	5.47	0.59	5.57	0.11	1.18	5.57
PY	18.01**	2.89*	1.75	0.19	1.79	0.11	0.38	1.79

* & ** Significant at 5% and 1 % level respectively

Note: DF= Days to 50% flowering, DM = Days to maturity, PH = Plant height,
PB = Number of primary branches per plant, SB = Number of secondary branches per plant,
NL = Number of leaves per plant, LAFD % = percentage of leaves affected by foliar diseases,
MP= Number of mature pods per plant, IMP = Number of immature pods per plant,
KY = Kernel yield per plant, SMK% = Sound mature kernel percentage,
SO = Shelling out-turn, LLSS = Late leaf spot severity, RS = Rust severity,
HI = Harvest index and PY = Pod yield per plant

height for short statured nature as it showed lowest mean plant height in combination with significant negative GCA. Foliar disease resistant parents, ICG (FDRS) 79 and GPBD 4 recorded significant negative GCA along with lower values of percentage of leaves affected by foliar diseases resistance and lower LLS and rust severities. Hence, these two lines can serve as good donors for incorporating foliar disease resistance in further breeding programmes aimed at development of high yielding foliar disease resistant genotypes. The parent, ICG (FDRS) 79 was also identified as best combiner with significant positive GCA with high *per se* performance for the traits namely, number of primary branches per plant, number of secondary branches per plant, number of leaves per plant, number of mature pods per plant, kernel yield per plant, harvest index and pod yield per plant. Hence, it is the best donor for incorporation of foliar disease resistance along with high yielding ability. GPBD 4 was the next best combiner for morphological traits, number of primary branches per plant, number of secondary branches per plant and pod yield per plant with significant positive GCA values. Narayani, TPT 25 and Kadiri 6 were the best combiners for number of immature pods per plant as they exhibited lower mean number of immature pods in combination with significant negative GCA.

Specific combining ability effects: The term, specific combining ability is used to designate those cases in which certain combinations do relatively better or worse than would be expected on the basis of the average performance of the lines involved (Griffing, 1956). Study of SCA effects along with *per se* performance of a cross combination for a particular trait will give clear picture of best specific combinations among crosses for each trait. The *per se* performance and SCA effects are presented in Table 5. From the results, it is clear that only limited cross combinations exhibited significant SCA effects for the studied traits. For days to 50% flowering, eight cross combinations registered significant negative SCA effects along with lower mean for days to flowering (Table 5). The parents involved in these eight crosses namely, Tirupati 1, Narayani and TLG 45 had also shown significant negative GCA for days to 50% flowering. For plant height, two crosses, Kadiri 6 × ICG (FDRS) 79 and TLG 45 × TCGS

TABLE 4: Mean and GCA of parents in desirable direction in groundnut

Trait	Mean	GCA of parents	Desirable direction
Days to 50% flowering	24.00	Narayani	For early flowering habit
	24.00	Tirupati-1	
	26.00	TLG 45	
	24.00	TPT 25	For late flowering habit
	26.00	ICG (FDRS) 79	
	25.00	TCGS 876	
Days to maturity	95.00	Narayani	For early maturing plants
	95.00	TLG 45	
	95.00	Kadiri 6	
	95.00	Tirupati 1	
	98.00	TPT 25	
	102.00	ICG (FDRS) 79	For late maturing plants
	102.00	GPBD 4	
Plant height at harvest (cm)	16.00	TLG 45	For short statured plants
	18.33	TPT 25	
	18.67	Kadiri 6	
	30.67	Narayani	For long statured plants
	29.33	ICG (FDRS) 79	
Number of primary branches per plant	9.00	ICG (FDRS) 79	For good number of primary branches
	8.00	TCGS 876	
	7.67	GPBD 4	
Number of secondary branches per plant	3.00	ICG (FDRS) 79	For good number of secondary branches
	2.67	GPBD 4	
Number of leaves per plant	53.33	ICG (FDRS) 79	For good number of leaves
Percentage of leaves affected by foliar diseases (%)	1.33	ICG (FDRS) 79	For least affected leaves by foliar diseases
	2.00	GPBD 4	
Number of mature pods per plant	16.33	ICG (FDRS) 79	For high number of mature pods
Number of immature pods per plant	2.00	TLG 45	For low number of immature pods
	4.00	TCGS 876	
Kernel yield per plant (g)	9.26	ICG (FDRS) 79	For high kernel yield
Sound mature kernel percentage	89.00	Narayani	For high SMKs
Shelling out-turn	61.33	TLG 45	For high shelling out-turn
Late leaf spot severity	5.74	ICG (FDRS) 79	For least LLS severity
	6.54	GPBD 4	
Rust severity	5.74	ICG (FDRS) 79	For least rust severity
	6.54	GPBD 4	
Harvest index (%)	48.33	Tirupati 1	For high Harvest index
Pod yield per plant (g)	19.35	ICG (FDRS) 79	For high Pod yield
	16.63	GPBD 4	

876 were identified as the best combinations as they registered significant negative SCA coupled with lower mean for plant height (Table 5).

From comparison of mean and SCA effects, TCGS 876 × GPBD 4 and TCGS 876 × ICG (FDRS) 79 were identified as best cross combinations for foliar disease resistant traits *viz.*, percentage of leaves affected by foliar diseases, LLS and rust severities. The parents involved in the above two crosses had also shown lower mean along with significant negative GCA for these foliar disease resistant traits. For number of primary branches per plant, number of leaves per plant, number of mature pods per plant, kernel yield per plant, TCGS 876 × ICG (FDRS) 79 identified as best cross combination with significant positive SCA and higher mean values. The crosses, Tirupati 1 × Kadiri 6 and TLG 45 × GPBD 4 were identified as good cross combinations for shelling out-turn. For harvest index and pod yield per plant, TPT 25 × GPBD 4 and Kadiri 6 × TLG 45 were identified as best crosses as they registered significant positive SCA coupled

TABLE 5: Mean and SCA of top five crosses (F_1s) in desirable direction in groundnut

Trait	Range of mean	Crosses
DF	24.33 - 26.67	Tirupati 1 × TCGS 876, Narayani × ICG (FDRS) 79, TLG 45 × ICG (FDRS) 79, TLG 45 × GPBD 4 & Narayani × GPBD 4 (-ve)
		TLG 45 × TCGS 876, Kadiri 6 × TLG 45, Narayani × TPT 25, Tirupati 1 × Narayani & Kadiri 6 × TCGS 876 (+ ve)
DM	97.33 - 101.67	Tirupati 1 × ICG (FDRS) 79, TCGS 876 × ICG (FDRS) 79, TLG 45 × TCGS 876 (+ve)
PH	16.00cm - 21.33cm	TLG 45 × TCGS 876, Kadiri 6 × ICG (FDRS) 79, (-ve)
	23.00cm – 33.67cm	Narayani × ICG (FDRS) 79, Kadiri 6 × TLG 45 (+ve)
PB	9.00	TCGS 876 × ICG (FDRS) 79
NL	46.67 - 65.00	TCGS 876 × ICG (FDRS) 79, TPT 25 × TLG 45, Tirupati 1 × Narayani, Kadiri 6 × TCGS 876, Narayani × Kadiri 6
%LAFD	5.00 - 14.33	Kadiri 6 × TCGS 76, TLG 45 × GPBD 4, TPT 25 × ICG (FDRS) 79, TLG 45 × ICG (FDRS) 79, Narayani × GPBD 4 (-ve)
MP	19.33 - 19.67	TPT 25 × GPBD 4, TCGS 876 × ICG (FDRS) 79
IMP	1.67 – 3.00	TCGS 876 × GPBD 4, TPT 25 × ICG (FDRS) 79, TCGS 876 × ICG (FDRS) 79, Tirupati 1 × GPBD 4 (-ve)
KY	11.46 - 11.72	TCGS 876 × ICG (FDRS) 79, TPT 25 × GPBD 4
SMK%	93.00 - 94.00	Narayani × ICG (FDRS) 79, Tirupati 1 × TPT 25
SO	61.00 – 63.67	TLG 45 × GPBD 4, Tirupati 1 × Kadiri 6
LLSS	6.54 – 13.73	TCGS 876 × GPBD 4, TPT 25 × Kadiri 6, TCGS 876 × ICG (FDRS) 79, GPBD 4 × ICG (FDRS) 79 (-ve)
RS	7.95 – 14.15	TCGS 876 × ICG (FDRS) 79, Tirupati 1 × Kadiri 6, TCGS 876 × GPBD 4 (-ve)
HI	54.00 - 68.67	Tirupati 1 × GPBD 4, Tirupati 1 × TLG 45, Narayani × TLG 45, Narayani × Kadiri 6, Kadiri 6 × TLG 45
PY	14.91 – 21.52	TPT 25 × GPBD 4, Kadiri 6 × TLG 45

Note: DF = Days to 50% flowering, DM = Days to maturity, PH = Plant height
PB = Number of primary branches per plant, SB = Number of secondary branches per plant,
NL = Number of leaves per plant, %LAFD = percentage of leaves affected by foliar diseases
MP = Number of mature pods per plant, IMP = Number of immature pods per plant,
KY = Kernel yield per plant, SMK% = Sound mature kernel percentage
SO = Shelling out-turn, LLSS = Late leaf spot severity, RS = Rust severity,
HI = Harvest index and PY = Pod yield per plant
For DF and PH depending on the situation significant positive and negative direction is desirable.

with higher mean. For number of immature pods per plant, the cross combinations, Tirupati 1 × Kadiri 6, TPT 25 × ICG (FDRS) 79, TCGS 876 × GPBD 4 and TCGS 876 × ICG (FDRS) 79 were identified as best cross combinations as they registered significant negative SCA effects coupled with lower mean number of immature pools.

Considering gene effects involving the inheritance of the studied traits, selection would be more difficult for majority of the traits studied because non-additive gene effects are predominant for these traits as the additive variance was found to be lower than dominance variance indicating that selection should be practiced in later generations. Whereas for late leaf spot severity, additive gene effects play a major role as the additive variance was found to be higher than dominance variance hence selection would be possible in early generations. Tirupati 1, Narayani and TLG 45 were found to be donor sources for incorporation of earliness. The line, TLG 45 also showed negative GCA for plant height and hence a good parental line for incorporation of dwarfness. ICG (FDRS) 79 and GPBD 4 are very good donor sources for transfer of late leaf spot and rust resistance along with many of yield attributes and yield. Narayani, TPT 25 and Kadiri 6 were the best combiners for number of immature pods per plant which can be involved as parents for uniform maturity.

Tirupati 1 × TLG 45, Tirupati 1 × TCGS 876 and Narayani × Kadiri 6 were identified as the best cross combinations to be advanced to select for early maturing segregants. Kadiri 6 × ICG (FDRS) 79 and TLG 45 × TCGS 876 were identified as the best crosses for improvement in plant height. For number of primary branches per plant, number of leaves per plant, number of mature pods per plant, kernel yield per plant and foliar disease resistance traits. TCGS 876 × ICG (FDRS) 79 is a good cross combination which has to be carefully handled in segregating generations as there is a lot of scope for getting desirable high yielding segregants with foliar disease resistance. The cross combination, TCGS 876 × GPBD 4 was identified as best combination for foliar disease resistant traits *viz.*, percentage of leaves affected by foliar diseases, LLS and rust severities. The crosses, Tirupati 1 × Kadiri 6 and TLG 45 × GPBD 4 have exhibited positive SCA effects for shelling out-turn. For harvest index and pod yield per plant, TPT 25 × GPBD 4 and Kadiri 6 × TLG 45 were identified as best cross combinations.

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