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GENERAL AND SPECIFIC COMBINING ABILITY ESTIMATES OF PHYSIOLOGICAL TRAITS FOR MOISTURE STRESS TOLERANCE IN GROUNDNUT (*ARACHIS HYPOGAEA* L.)

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ABSTRACT: The combining abilities for physiological traits in peanut were examined to understand the type of gene action governing these traits, and to identify peanut genotypes suitable for use as parents in breeding for improvement in physiological traits. Substantial genetic variability was observed among the hybrids for the traits studied. The genotypes, TPT-4 and ICGV-91114 were found to be good combiners for developing early flowering types, while ICGV-91114, TCGS- 584, TPT-4 and JL-220 were good combiners for developing early maturing. For SPAD chlorophyll meter reading was K-1375 was best general combiner. Among the parents K-1375, TIR-25 and TCGS-647 were found to be superior as evident from its highest significant positive general combining ability effects for specific leaf area. The best good combiner for transpiration rate was ICGV-91114 and for photosynthetic rate was TIR-25. For water use efficiency only the genotype, TPT-4 was the best combiner. Best performing parents for harvest index were JL-220 and TPT-4. The hybrid, TPT-4 x TIR-25 was the specific hybrid for high water use efficiency. For SPAD chlorophyll meter reading only one cross, K-1375 x TCGS647 was considered to be the good performing hybrid. Two hybrids *viz.*, TIR-25 x TCGS-647 and ICGV-91114 x JL-220 were found to be good specific combiners for harvest index. A perusal of results of combining ability analysis indicated considerable non-additive gene action in the inheritance of majority of the attributes studied. The non-fixable dominance deviation and epistatic effects are likely to hinder improvement through simple pedigree selection, which is commonly followed in groundnut. Alternatively intermating of the F_2 segregants followed by recurrent selection and pedigree breeding can harness the different kinds of gene - effects. Repeated selection and inter-mating of segregating materials for two or three cycles, makes it possible to achieve simultaneously improvement in physiological attributes.

Keywords: *Arachis hypogaea*, general combining ability, specific combining ability, diallel analysis, physiological traits

INTRODUCTION

Peanut or groundnut is an important oilseed crop is sown mostly under rain-dependent production conditions in India, as a sole crop or intercrop with pigeon pea, castor, cotton and sesame etc. Due to erratic rainfall and frequent drought, and also lack of high yielding adapted cultivars, groundnut yields are generally low and unstable under rain-dependent conditions. Though, groundnut is known for its relative ability to withstand periods of water limited conditions still produce biomass and kernels, requires through investigations to increase eater use efficiency (WUE), to assure sustained food security for the benefit of resource poor farmers in the semi arid regions. Several reviews (Blim, 1988 and Lawn, 1989) have considered the value of physiological or morphological attributes in breeding improved cultivars of crop species. recent researchers breakthroughs have revived interest in targeted drought resistance breeding and use of new genomic tools to enhance crop WUE. However, with the fast progress in genomics, a better understanding of the gene functions and physiological mechanism for moisture stress tolerance will also be essential for the progress of genetic enhancement of crop for WUE.

In any breeding programme knowledge of the genetic composition of the breeding stocks in hand and the nature of gene action involved in the expression of the trait to be improved is the basic requirement of the breeder. Diallel is an efficient method for the study of combining ability as well as the gene action involved. In diallel analysis Sprague and Tatum (1942) introduced the concept of general combining ability and specific combining ability. General combining ability is associated with genes which are additive in effects while specific combining ability is attributed primarily deviations from the additive scheme caused by dominance and epistasis (Rojas and Sprague, 1952). The knowledge on combining ability and type of gene action responsible for the regulation of expression of different traits would certainly help in planning appropriate breeding strategies.

From the available reports it is evident that information on the precise nature of genetic control of physiological traits in peanut is still lacking. The objective of the current study to estimate the relative importance of additive and non additive gene action in controlling the inheritance of certain physiological traits in a 8 x 8 half diallel mating design in peanut, besides identification of good general combiners to be used as donor parents for the improvement of these traits. The study also aimed at the identification of specific cross combinations with good combining ability for the improvement of physiological traits especially water use efficiency traits.

MATERIALS AND METHODS

Twenty eight F_1s crosses were obtained by making eight parents viz., TPT-4, TIR-25, ICTGV-91114, TCGS-584, JL-220, ICGV-99025, TCGS-647 and K-1375 in diallel manner without reciprocals. Twenty eight F_1s along with eight parents were sown in a Randomised Block Design (RBD) with three replications during *kharif* 2009. Each parent was sown in 3 rows of 3 m length while F_1s were raised in a single row of 3 m length. Ten random plants per replication were sampled in case of parents and F_1s per replication were tagged at random for recording observations. Observations were recorded on ten random plants in parents and F_1 in each treatment per replication. The experiment was conducted in a red sandy loam soil with a neutral pH, low in organic carbon. Recommended agronomic and plant protection measures were adopted for the conduct of experiment.

Statistical analysis

The data collected on sampled plants in all the entries in different replications were averaged (replication wise) and mean values were subjected for statistical analysis.

Combining ability analysis

The combining ability analysis was carried out according to Model I and Method II of Griffing (1956). The fixed effect model (Model I) was considered to be more appropriate in the present investigation since the study was restricted to the parents and direct crosses only. By taking square roots of the variances, the corresponding standard errors required for testing were obtained.

RESULTS AND DISCUSSION

The analysis of variance for the experiment revealed significant differences due to genotypes (parents and F1s) for all the twelve physiological traits studied suggesting the existence of substantial genetic variability (Table 1). The variance due to specific combining ability was greater than the variance due to general combining ability for all the traits (Table 2. This indicates the predominance of non – additive gene action for these traits. Hence improvement of these physiological traits could be accomplished by selection of crosses having high sca effects and advancing progenies to later filial generations.

Table 1. Analysis of variance (Mean squares) of physiological traits for moisture stress tolerance among 8 parents and 28 F_1s of groundnut.

Character	Replications d.f. = 2	Treatments d.f. = 35	Error d.f. = 70
Days to 50 per cent flowering	0.2322	11.8117**	0.7838
Days to maturity	2.5069	25.2417**	1.7950
SPAD chlorophyll meter reading	2.4783	12.2698*	6.6601
Specific leaf area	482.4722	43.3381**	790.7603
Specific leaf weight	0.4059	1.0926**	0.3547
Leaf area index	0.0649	0 .0653**	0.0259
Transpiration rate	1.8876	1.5423*	0.9204
Photosynthetic rate	6.8121	9.5300**	3.5806
Stomatal conductance	1.9993	1.2144*	0.7372
Water use efficiency	0.0028	0.0046*	0.0027
Dry haulm weight per plant	140.9358	299.0510**	73.0272
Harvest index	40.4974	74.7647**	21.2815

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

The estimates of general combining ability (gca) effects of the eight parents and specific combining ability (sca) effects of 28 crosses for physiological characters are presented in Tables 3 and 4.

Days to 50 per cent flowering

Estimates of gca effects for days to 50 per cent flowering varied from -1.80 (Tirupati-4) to 1.13 (ICGV-99029). Three parental genotypes *viz.,* TIR-25 (0.37). TCGS-584 (0.20), JL-220 (0.13), ICGV-99029 (1.13) and TCGS-647 (1.07) showed significant positive gca effects. The parents, TPT-4 (-1.80), ICGV-91114 (-1.00) and K-1375 (-0.10) registered significant negative gca effects (Table 3).

Table 2. Analysis of variance for combining ability of physiological (water use efficiency) traits for moisture stress tolerance among 8 parents and 28 F_1s of groundnut.

Source	d.f.	Days to 50 per cent flowering	Days to maturity	SPAD chlorophyll meter reading at 60 DAS	Specific leaf area at 60 DAS	Specific leaf weight at 60 DAS	Leaf area index at 60 DAS	Transpiration rate at 60 DAS	Transpiration rate at 60 DAS	Stomatal conductance at 60 DAS	WUE (%) at 60 DAS	Dry haulm weight per plant	Harvest index
Gca	7	9.81**	17.13**	9.54**	813.93**	0.40**	0.03*	0.74*	4.03**	0.44	0.002	227.14**	75.24**
Sca	28	2.45**	6.24**	2.73	768.79**	0.36**	0.02**	0.46	2.96**	0.40	0.001	67.82**	12.34*
Error	70	0.26	0.60	2.22	218.97	0.12	0.01	0.31	1.19	0.25	0.001	24.34	7.09
Var. (gca)		0.03	0.06	0.24	23.74	0.01	0.001	0.03	0.13	0.03	0.000	2.64	0.77
Var. (sca)		0.27	0.61	2.26	223.11	0.12	0.009	0.31	1.22	0.25	0.001	24.80	7.23

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

Table 3. Estimates of general combining ability effects physiological (water use efficiency) traits for moisture stress tolerance among 8 parents of groundnut.

Parents	Days to 50 per cent flowering	Days to maturity	SPAD chlorophyll meter reading	Specific leaf area	Specific leaf weight	Leaf area index	Transpiration rate	Photosynthetic rate	Stomatal conductance	WUE	Dry haulm weight per plant	Harvest index
TPT-4	-1.80**	-1.06**	-1.31**	4.86	-0.09	0.08**	-0.27	0.01	0.24	0.02**	-2.55	2.10**
TIR-25	0.37*	1.24**	-0.49	-9.51*	0.21*	-0.0002	0.22	0.88**	0.18	0.01	2.41	0.28
ICGV-91114	-1.00**	-1.76**	-0.08	-0.17	-0.05	0.02	0.56**	0.21	-0.07	-0.01	-0.86	0.88
TCGS-584	0.20	-1.09**	-0.52	5.07	-0.09	-0.04	-0.07	-1.01**	-0.41**	-0.01	-4.70**	0.80
JL-220	0.13	-0.73**	0.11	4.95	-0.13	0.06*	-0.19	-0.71*	-0.12	-0.02	-3.82*	2.58**
ICGV-99029	1.13**	1.58**	0.34	14.49**	-0.31**	-0.04	-0.09	0.61	0.12	-0.003	10.42**	-5.99**
K-1375	-0.10	0.48*	2.08**	-10.80*	0.25*	-0.06*	-0.15	0.23	0.11	0.01	-0.80	1.10
TCGS-647	1.07**	1.34**	-0.13	-8.89*	0.20	-0.01	-0.01	-0.22	-0.07	-0.01	-0.10	-1.75*

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

The estimates of sca effects ranged from –1.67 (ICGV-91114 x TCGS-647) to 0.84 (TIR-25 x TCGS-584). Among 28 F_1s studied only six F_1s *viz.,* Tirupati-4 x ICGV-91114, TIR-25 x ICGV-91114, TIR-25 x TCGS-584, TIR-25 x K-1375, TCGS-584 x TCGS-647 and K-1375 x TCGS-647 displayed positive sca effects in desirable direction and thirteen F_1s expressed significant negative sca effects (Table 4).

Table 4. Estimates of specific combining ability effects for physiological (water use efficiency) traits for moisture stress tolerance among 28 F_1s of groundnut.

Crosses	Days to 50 per cent flowering	Days to maturity	SPAD chlorophyll meter reading at 60 DAS	Specific leaf area at 60 DAS	Specific leaf weight at 60 DAS	Leaf area index at 60 DAS	Transpiration rate at 60 DAS	Photo-synthetic rate at 60 DAS	Stomatal conductance at 60 DAS	WUE (%) at 60 DAS	Dry haulm weight per plant	Harvest index
TPT-4 x TPT-25	-0.49	-3.06**	0.81	-10.53	0.20	0.05	-0.34	0.41	-0.10	0.09**	1.47	-1.98
TPT-4 x ICGV-91114	0.54	0.94	-0.27	12.03	-0.27	0.10	0.07	-0.72	0.64	0.04	0.13	-0.56
TPT-4 x TCGS-584	-1.66**	-1.06	-1.16	25.73	-0.58	0.03	-0.52	1.37	0.26	0.05	6.45	1.80
TPT-4 x JL-220	-0.93*	-1.10	-0.86	-36.95**	0.76*	-0.06	0.02	-0.83	-0.72	-0.02	3.62	0.53
TPT-4 x ICGV-99029	-1.26**	-2.73**	-1.59	15.94	-0.32	0.10	0.44	-0.66	0.81	-0.03	-6.91	0.96
TPT-4 x K-1375	-0.36	-0.96	-0.16	32.73	-0.77*	0.23**	0.11	-0.64	-0.16	-0.03	3.34	-0.20
TPT-4 x TCGS-647	-1.19*	-0.50	-0.62	-45.05**	1.26**	0.01	0.69	2.58*	0.41	-0.01	0.85	2.89
TIR-25 x ICGV-91114	0.04	-0.03	0.64	9.42	-0.25	0.15	-0.70	-0.46	0.34	0.00	-4.93	-1.39
TIR-25 x TCGS-584	0.84	-0.36	1.68	10.19	-0.30	0.16	0.30	0.10	0.14	-0.04	-1.32	4.65
TIR-25 x JL-220	-0.93	-0.73	0.02	32.59*	0.78*	-0.24**	0.83	1.17	0.13	0.01	-3.08	0.97
TIR-25 x ICGV-99029	-1.09*	-1.03	-0.91	-6.00	0.05	-0.00	-0.15	-0.36	-0.28	-0.01	25.09**	-4.32
TIR-25 x K-1375	0.14	-2.93**	-3.84**	-5.81	0.10	0.13	0.59	-1.11	-0.35	-0.02	9.68*	-4.22
TIR-25 x TCGS-647	-1.36**	-3.80**	1.43	40.18**	-0.63*	-0.00	1.26*	-2.23*	-0.85	-0.08**	-8.92	6.35*
ICGV-91114 X TCGS-584	-1.13*	1.30	0.27	-37.12**	0.81*	-0.08	0.75	-0.40	0.36	-0.04	-5.82	4.26
ICGV-91114 X JL-220	-0.73	0.27	-1.55	-0.96	0.03	-0.20*	0.11	4.13*	-0.29	0.04	3.62	5.23*
ICGV-91114 X ICGV-99029	-1.06*	-1.03	2.15	-11.74	0.34	-0.06	0.65	-0.86	-0.66	-0.03	9.66*	-1.03
ICGV-91114 X K-1375	-0.83	1.07	-0.89	-17.01	0.40	-0.01	0.27	-1.18	-0.82	-0.02	0.38	3.90
ICGV-91114 X TCGS-647	-1.67**	-1.80*	-0.88	26.14	-0.75*	0.04	0.48	-0.19	-0.51	-0.03	9.35*	-0.78
TCGS-584 X JL-220	-0.59	0.60	0.25	38.04**	-0.69*	-0.08	0.64	1.09	-0.23	-0.01	-5.99	1.66
TCGS-584 X ICGV-99029	-0.93*	-1.70*	0.22	42.99**	-0.68*	0.18*	-0.09	1.13	-0.33	0.05	2.07	-3.45
TCGS-584 X K-1375	-0.03	2.40**	-0.15	-29.38*	0.61	-0.22*	-0.82	0.91	-0.45	0.04	0.86	-1.90
TCGS-584 X TCGS-647	0.14	0.87	-0.47	-30.83*	0.67*	0.02	-0.33	-0.54	-0.08	-0.00	3.83	-2.69
JL-220 X ICGV-99029	-0.19	0.94	0.73	-24.48	0.47	0.27**	-1.55**	-1.74	-0.98*	-0.01	9.68*	-0.64
JL-220 X K-1375	-0.63	-1.30	2.49	42.58*	-0.89*	-0.00	0.79	0.88	-0.09	-0.02	-8.03	2.75
JL-220 X TCGS-647	-1.13*	-1.16	0.80	5.83	-0.23	0.06	-0.37	-1.60	-0.38	0.01	3.50	-3.34
ICGV-99029 x K-1375	-0.96*	-2.93**	-3.01*	7.56	-0.30	-0.10	0.52	0.82	1.20**	-0.01	-2.60	-3.72
ICGV-99029 x TCGS-647	-1.46**	-1.46*	-0.70	-29.48*	0.55	0.11	0.08	2.74	0.40	0.02	-2.60	4.24
K-1375 x TCGS-647	0.11	0.97	3.63**	-28.32*	0.48	-0.12	-0.29	3.45**	-0.47	0.05	2.93	2.71
SE (Sij)	0.52	0.78	1.50	14.94	0.35	0.09	0.56	1.10	0.50	0.03	4.98	2.69

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

The genotypes, TPT-4 and ICGV-91114 were found to be good combiners for developing early flowering types (Less number of days for 50 per cent flowering) (Fig. 1). The best specific combiners for early flowering were ICGV-91114 x TCGS-647, TPT-4 x ICGV-99029, ICGV-91114 x ICGV-99029, TPT-4 x JL-220, TCGS-584 x ICGV-99029 and TIR-25 x ICGV-99029, TPT-4 x TCGS-584, ICGV-99029 x TCGS-647, TIR-25 x TCGS-647, TPT-4 x TCGS-647, JL-220 x TCGS-647, ICGV-91114 x TCGS-584 and ICGV-99029 x K-1375.

Days to maturity

Estimates of gca effects for days to maturity varied from –1.76 (ICGV-91114) to 1.58 (ICGV-99029). Four parental genotypes *viz.,* TIR-25 (1.24), ICGV-99029 (1.58), K-1375 (0.48) and TCGS-647 (1.34) showed significant positive gca effects. The parents, Tirupati-4 (-1.06), ICGV-91114 (-1.76), TCGS-584 (-1.09) and JL-220 (-0.73) registered significant negative gca effects (Table 3).

The estimates of sca effects ranged from –3.80 (TIR-25 x TCGS-647) to 2.40 (TCGS-584 x K-1375). Among 28 F_1s studied only one F_1 TCGS-584 x K-1375 showed significant positive sca effect and eight F_1s *viz.,* TPT-4 x ICGV-91114, ICGV-91114 x TCGS-584, ICGV-91114 x JL-220, ICGV-91114 x K-1375, TCGS-584 x JL-220 TCGS-584 x TCGS-647, JL-220 x ICGV-99029 and K-1375 x TCGS-647 displayed positive sca effects in desirable direction and eight F_1s expressed significant negative sca effects.

The genotypes *viz*., ICGV-91114, TCGS- 584, TPT-4 and JL-220 were good combiners for developing early maturing cultivars (Fig. 2). Similar results were also reported by Adamu *et al.* (2008), Sharma and Gupta (2008), Rekha *et al.* (2009) and Savithramma *et al.* (2010).

SPAD chlorophyll meter reading (SCMR)

Estimates of gca effects for SCMR varied from -1.31 (Tirupati-4) to 2.08 (K-1375). Only one parental genotype *viz.,* K-1375 (2.08) showed significant positive gca effect. JL-220 and ICGV-99029 exhibited positive effects. The parent, Tirupati-4 (-1.31) registered significant negative gca effects (Table 3).

The estimates of sca effects ranged from –3.84 (TIR-25 x K-1375) to 3.63 (K-1375 x TCGS-647). Among 28 F_1s studied only one F_1s *viz.,* K-1375 x TCGS-647 (3.63 displayed significant positive sca effects in desirable direction and two F_1s expressed significant negative sca effects.

Significant positive gca effect for SPAD chlorophyll meter reading was registered by K-1375. This genotype was considered to good general combiners (Fig. 3). For SPAD chlorophyll meter reading only one cross, K-1375 x TCGS647 was considered to be the good performing hybrid. The cross combinations that showed high sca and higher *per se* performance was either H x L or H x H combinations. These results indicate the role of inter-allelic interactions in displaying higher sca and high *per se* performance.

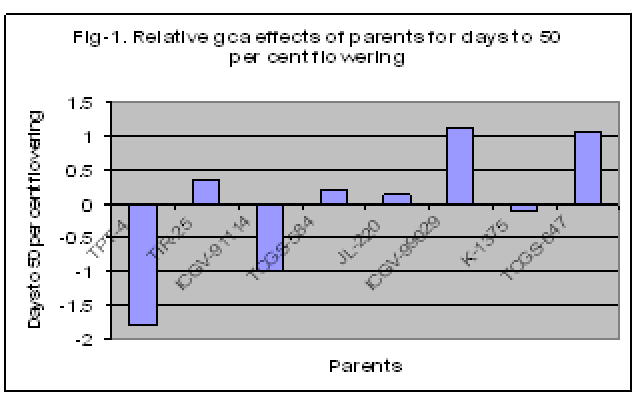


Fig-2. Relative gca effects of parents for days to maturity

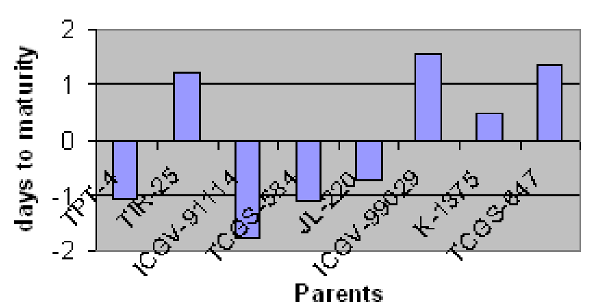
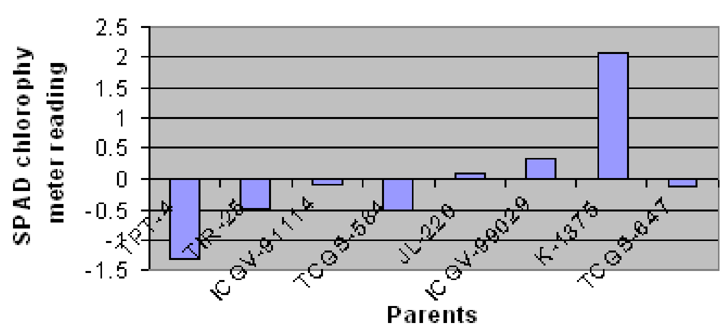


Fig-3. Relative gca effects of parents for SPAD chlorophyll meter reading



This also could be due to genetic interaction between favorable alleles contributed by the parents involved. The recurrent selection and diallel mating system, that provide an opportunity for selection, recombination and accumulation of the desired genes and also to exploit fixable and non-fixable type of genes in later generations, should be employed for improvement of SCMR in these combinations. Vasanthi *et al.* (2004) and Seethala Devi (2004) and Venkateswarlu *et al.* (2007) also reported non-additive gene action for SCMR in segregating generation of groundnut.

Specific leaf area

Among parents, K-1375 recorded highly significant negative gca effect (-10.80). The gca effects varied from –10.80 (K-1375) to 14.49 (ICGV-99029). Positive and significant gca effect was shown by ICGV-99029. Significant negative gca effects were registered by TIR-25(-9.51), K-1375 (-10.80) and TCGS-647 (-8.89).

Sca effects for specific leaf area ranged from -45.05 (Tirupati-4 x TCGS-647) to 42.99 (TCGS-584 x ICGV-99029). Five F_1s *viz.,* TIR-25 x JL-220, TIR-25 x TCGS-647, TCGS-584 x JL-220, TCGS-584 x ICGV-99029 and JL-220 x K-1375 exhibited significant positive sca effects in desirable direction. As many as seven F_1s showed significant negative sca effects.

The estimates of gca effects showed that among the parents K-1375, TIR-25 and TCGS-647 were found to be superior as evident from its highest significant positive general combining ability effects for specific leaf area (Fig. 4). The best performing hybrids for specific leaf area were TPT-4 xTCGS-647, ICGV-91114 x TCGS-584, TPT-4 xKL-220, TCGS-584 x TCGS-647, TCGS-584 x K-1375 and ICGV-99029 x TCGS-647. These results were confirmed with the findings of Jayalakshmi *et al.* (1999) and Nigam *et al.* (2001) also reported additive gene action for SLA in groundnut, however Vasanthi *et al.* (2004) and Venkateswarlu *et al.* (2007), reported non-additive gene action for SLA in groundnut.

Specific leaf weight

The gca effects for specific leaf weight varied from -0.31 (ICGV-99029) to 0.25 (K-1375). Positive and significant gca effects were shown by TIR-25 and K-1375. Significant negative gca effect was registered by (ICGV-99029).

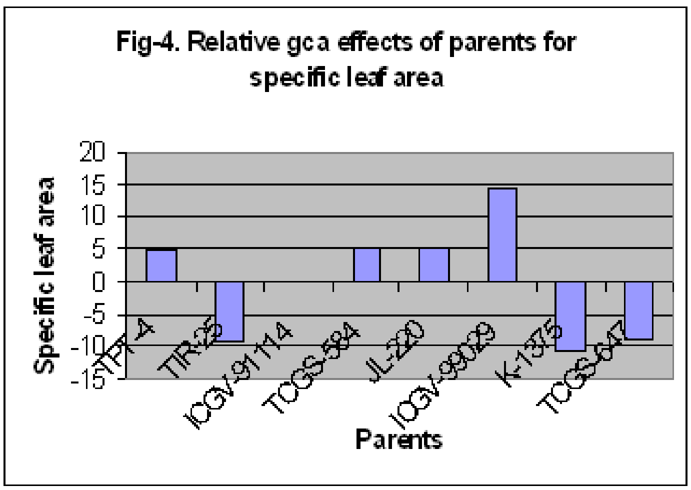
Sca effects for specific leaf weight ranged from -0.89 (JL-220 x -1375) to 1.26 (Tirupati-4 x TCGS-647). Five F_1s *viz.,* TPT-4 x JL-220, Tirupati-4 x TCGS-647, TIR-25 x JL-220, ICGV-91114 x TCGS-584, and TCGS-584 x TCGS-647 exhibited significant positive sca effects in desirable direction. As many as six F_1s showed significant negative sca effects.

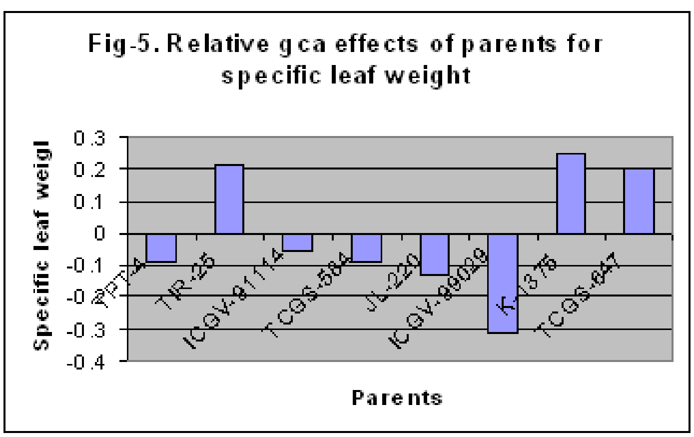
K-1375 and TIR-25 were found to be best general combiners for developing the genotypes with high specific leaf weight (Fig. 5). The F_1s,TPT-4 x TCGs-647, ICGV-91114 x TCGS-584, TIR-25 x JL-220, TPT-4 x JL-220 and TCGS-584 x TCGS-647 were observed to be the best specific combinations for specific leaf weight.

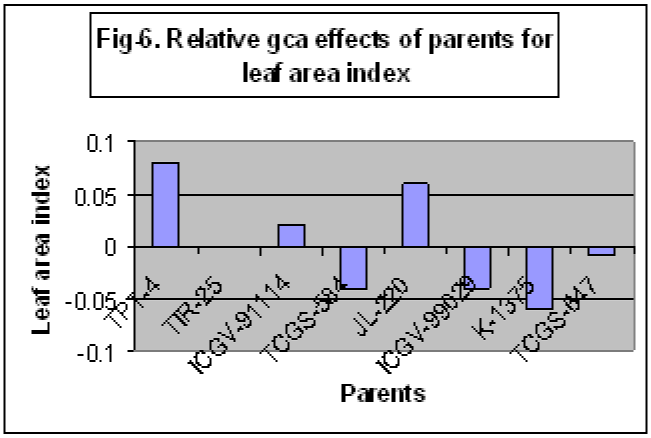
Leaf area index

The gca effects for leaf area index varied from –0.06 (K-1375) to 0.08 (TPT-4). Positive and significant gca effects were shown by Tirupati-4 and JL-220. Significant negative gca effect was registered by K-1375. The best specific combiner for leaf area index was K-1375 (Fig. 6).

Sca effects for leaf area index ranged from -0.24 (TIR-25 x JL-220) to 0.27 (JL-220 x ICGV-99029). Three F_1s *viz.,* TPT-4 x K-1375, TCGS-584 x ICGV-99029 and JL-220 x ICGV-91114 exhibited significant positive sca effects in desirable direction. As many as three F_1s showed significant negative sca effects. The best specific combiners for leaf area index were TIR-24 x JL-220, TCGS-584 x K-1375 and ICGV-91114 x JL-220.







Transpiration rate

Estimates of gca effects for transpiration rate varied from -0.27 (Tirupati-4) to 0.56 (ICGV-91114). Only one parental genotype *viz.,* ICGV-91114 (0.56) showed significant positive gca effect and TIR-25 exhibited positive effect. Six parents, showed negative gca effects. The best specific combiner for transpiration rate was ICGV-91114 (Fig. 7).

The estimates of sca effects ranged from -1.55 (JL-220 x ICGV-99029) to 1.26 (TIR-25 x TCGS-647). Among 28 F_1s studied only one F_1s *viz.,* TIR-25 x TCGS-647 (1.26) displayed significant positive sca effect in desirable direction and one F_1 expressed significant negative sca effect. The best specific combiners for transpiration rate were JL-220 x ICGV-99029 and ICGV-91114 x ICGV-99029.

Photosynthetic rate

The gca effects for photosynthetic rate varied from -1.01 (TCGS-584) to 0.88 (TIR-25). Positive and significant gca effect was shown by TIR-25. Significant negative gca effects were registered by TCGS-584 and JL-220. The best specific combiner for photosynthetic rate was TIR-25 (Fig. 8)

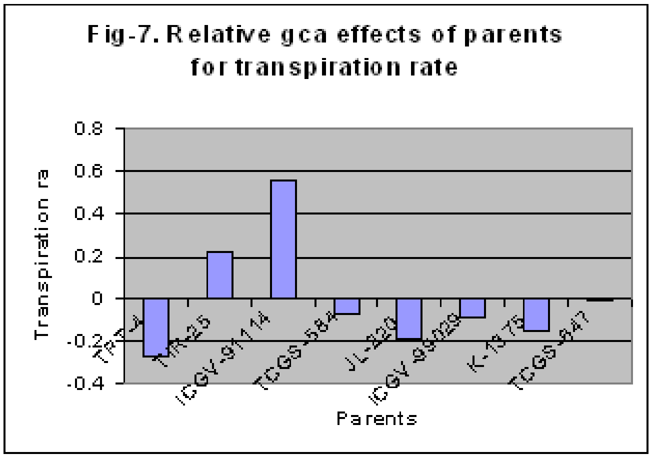
Sca effects for photosynthetic rate ranged from -1.74 (JL-220 x ICGV-99029) to 4.13 (ICGV-91114 x JL-220). Three F_1s *viz.,* Tirupati-4 x TCGS-647, ICGV-91114 x JL-220 and -1375 x TCGS -647 exhibited significant positive sca effects in desirable direction. Only one F_1 showed significant negative sca effects.

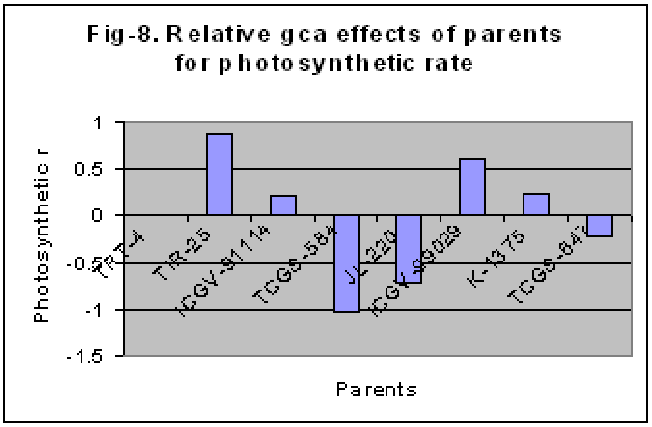
The hybrids, ICGV-91114 x Jl-220, K-1375 x TCGS-647 and TPT-4 x TCGS-647 were identified as the best superior specific cross combinations for photosynthetic rate Stomatal conductance

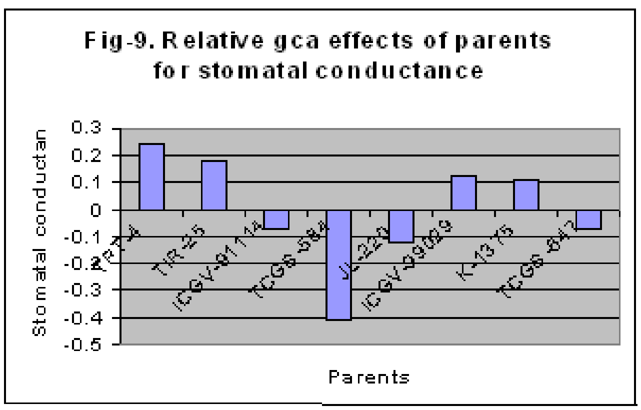
The gca effects for stomata conductance varied from –0.41 (TCGS-584) to 0.24 (TPT-4). Positive gca effects were shown by Tirupati-4, ICGV-99029 and K-1375. Significant negative gca effect was registered by TCGS-584.

Sca effects for stomatal conductance ranged from -0.98 (JL-220 x ICGV-99029) to 1.20 (ICGV-99029 x K-1375). Only one F1 viz., ICGV-99029 x K-1375 exhibited significant positive sca effect in desirable direction and one F1 showed significant negative sca effects.

Three parental genotypes, TIR-25, K-1375 and TCGS-584 were considered to be good combiners for stomatal conductance (Fig. 9). Only one hybrid, JL-220 x ICGV-99029 was appeared to be the good specific combiner for stomatal conductance.







Water use efficiency

The gca effects for water use efficiency varied from –0.02 (JL-220) to 0.02 (TPT-4). Positive and significant gca effect was shown by Tirupati-4 and TIR-25 and -1375 exhibited positive gca effects.

Sca effects for water use efficiency ranged from -0.08 (TIR-25 x TCGS-647) to 0.09 (TPT-4 x TIR-25). Only one F_1 *viz.,* Tirupati-4 x TIR-25 exhibited significant positive sca effect in desirable direction and one F_1 showed significant negative sca effect.

For water use efficiency only the genotype, TPT-4 was the best combiners (Fig. 10). Only one hybrid, TPT-4 x TIR-25 was the specific hybrid for high water use efficiency as evident from its high significant and positive sca effects.

Dry haulm weight per plant

The gca effects for dry haulm weight per plant varied from -4.70 (TCGS-584) to 10.42 (ICGV-99029). Positive and significant gca effect was shown by ICGV-99029. TCGS-584 and JL-220 were exhibited significant and positive gca effects.

Sca effects for dry haulm weight per plant ranged from -8.03 (JL-220 x K-1375) to 25.09 (TIR-25 x ICGV-99029). Five F_1s *viz.,* TIR-25 x ICGV-99029 (25.09), TIR-25 x K-1375 (9.68), ICGV-91114 x ICGV-99029 (9.66), ICGV-91114 x TCGS-647 (9.35) and JL-220 x ICGV-99029 (9.68) exhibited significant positive sca effects in desirable direction.

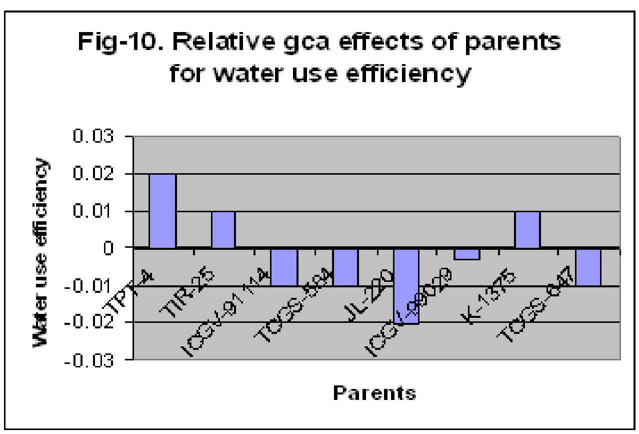
ICGV-99029 was appeared to be good combiners from its highest significant positive effects for dry haulms yield per plant (Fig.11). ICGV-91114 x ICGV-99029, TIR-25 x ICGV-99029, JL-220 x ICGV-99029 and ICGV-91114 x TCGS-647 were observed to be the best specific cross combinations for dry haulms yield per plant. These results are in agreement with the findings of Adamu *et al.* (2008).

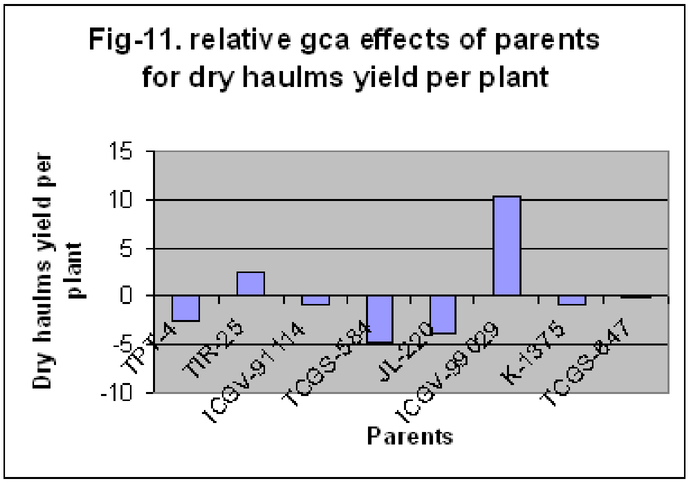
Harvest index

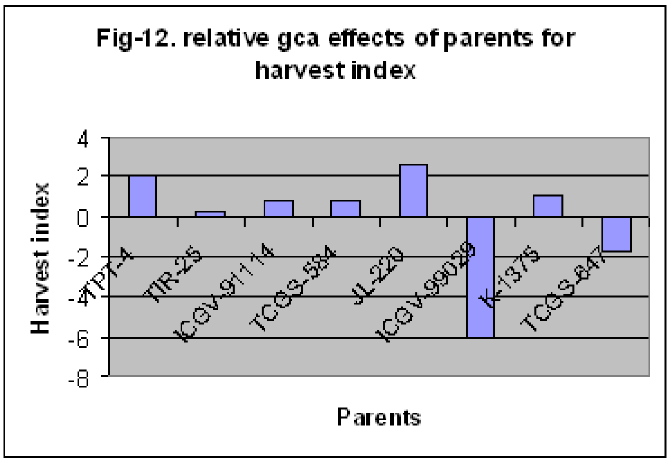
The parental gca effects for harvest index were ranged from -5.99 (ICGV-99029) to 2.58 (JL-220). Two genotypes *viz.,* Tirupati-4 and JL-220 exhibited significant positive gca effects, while ICGV-99029 and TCGS-647 showed significant negative gca effects.

The sca effects for harvest index ranged between –4.32 (TIR-25 x ICGV-99029) and 6.35 (TIR-25 x TCGS-647). Two F_1s exhibited significant positive sca effects *viz.,* TIR-25 x TCGS-647 and ICGV-91114 x JL-220.

The best performing parents for harvest index were JL-220 and TPT-4 (Fig-12) and two hybrids *viz.*, TIR-25 x TCGS-647 and ICGV-91114 x JL-220 were found to be good specific combiners as evident from its significant positive sca effects. Exploitation for this trait might also be possible in H x L and L x L cross combinations by use of biparental mating in F_2 or the use of selection procedure such as diallel selective matings. Importance of non-additive gene action in the inheritance of this character was reported by Makne (1992), Suresh Kumar (1993) and Nisar Ahmed (1995). However, Varman and Raveendran (1994) and Dwivedi *et al.* (1998) and Venkateswarlu *et al.* (2007) were reported importance of both additive and non-additive gene action for harvest index in groundnut.







A perusal of results of combining ability analysis indicated considerable non-additive gene action in the inheritance of majority of the attributes studied. The non-fixable dominance deviation and epistatic effects are likely to hinder improvement through simple pedigree selection, which is commonly followed in groundnut. Under such situations, breeding procedures have to be amended suitably by postponing the selection to later generations (Baker, 1968). Alternatively intermating of the F_2 segregants followed by recurrent selection and pedigree breeding can harness the different kinds of gene - effects. Repeated selection and inter-mating of segregating materials for two or three cycles, makes it possible to achieve simultaneously improvement in physiological attributes.

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