Estimation of Heterosis and Combining Ability of Yield Traits in Groundnut (*Arachis hypogaea* L.)

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**ABSTRACT**

**Background:** Groundnut, an important oilseed crop is grown in about 100 countries for oil and kernel. The kernels of groundnut also serves multiple table purposes as rough snacks to other value added product other than oil. Its importance is well experienced in the area occupied by it around the world among oilseeds in which it stands within top five. There is a constant thrust in increasing the productivity of groundnut among the cultivators seeking which the present study is taken up.

**Methods:** *L × T* analysis was taken up to estimate the gene action of yield and yield contributing traits for their improvement. 5 lines viz., CO 7, ICGV 07222, VRI 6, VRI 8 and GPBD 4 and 5 testers viz., VRI 3, Chico, Gangapuri, ICGV 91114 and ICGV 93468 were crossed to obtain 25 crosses. The *L × T* analysis was carried out on the biometrical data recorded. GCA and SCA variance revealed the importance of both additive and non-additive gene action of all the traits.

**Result:** Pod yield and kernel yield per plant were governed by non-additive gene action suggesting the advancement of the generation for selection to improve these traits. The parents ICGV 07222, VRI 8, Chico and ICGV 91114 were estimated to be best combiners for the inclusion in further breeding programs. The cross ICGV 07222 × Chico, a product of good combiners was best performing and can be used to obtain superior recombinants. Standard heterosis of 27% was observed for pod yield in the groundnut crosses.

**Key words:** Additive gene action, Good combiners, *L × T* analysis, Non-additive gene action, Standard heterosis, Yield traits.

**INTRODUCTION**

Groundnut is a unique leguminous crop called the “Wonder Legume” as it can be used in diverse ways due to its nutritional, medicinal and fodder values. The crop ranks first in India among the oilseeds grown in the states of Andhra Pradesh, Gujarat, Tamil Nadu, Karnataka and Maharashtra. New varieties with improved agronomic traits have been the major factor in increased food production.

Genes are the functional units that govern the development of various characters of an individual. Gene action refers to the behavior or mode of expression of genes in a genetic population and the understanding of gene action is important to plant breeders. Knowledge of gene action in plant breeding helps in selection of parents for use in the hybridization programmes, in choice of appropriate breeding procedure for the genetic improvement of various quantitative traits.

Tremendous genetic variation for pod yield and its components is available in the gene pool of groundnut which can be exploited for future. To bridge this yield gap, evolving new improved groundnut varieties are very much essential. In this context, the information on the combining ability of parents and the nature of gene action of yield its components would help in understanding the inheritance of characters, selection of suitable parents for hybridization and identification of promising early generation crosses to design an appropriate and efficient breeding strategy.

*L × T* analysis is one of the most powerful tools for predicting the general combining ability (GCA) of parents and selecting of suitable parents and crosses with high specific combining ability (SCA) (Rashid et al. 2007). *L × T* analysis provides information about combining ability effects of genotypes and also, knowledge regarding genetic mechanism controlling yield components. Information of GCA and SCA influencing yield and its components has become increasingly important to plant breeders to select appropriate parents for developing hybrid cultivars especially in cross pollinated crops. Many researchers have studied the combining abilities and gene actions of self-pollinated crop also using *L×T* analysis for some traits (Jain and Sastry, 2012).

With objective of understanding the genetics of yield and yield components in groundnut the present study of *L × T* analysis was taken up. Ten groundnut cultivars from different sources viz., Tamil Nadu Agricultural University, Coimbatore; Regional Research Station, Vridhachalam, Department of Oilseeds, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore 641 003, Tamil Nadu, India.

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Tamil Nadu and ICRISAT, Hyderabad were used in the study. Gene action and heterosis for various yield contributing traits and yield was determined from the crosses obtained.

**MATERIALS AND METHODS**

The popular groundnut varieties CO 7, ICGV 07222, VRI 6, VRI 8 and GPBD 4 were selected as lines (L) and the varieties VRI 3, Chico, Gangapuri, ICGV 91114 and ICGV 93468 were selected as testers (T). The L×T taken up for the study varied among themselves in several traits viz., plant height, days to flowering, pod yield, days to maturity and kernel colour. This difference of traits was used to identify the true F₁s among the crosses made. The lines and the testers were crossed by hand emasculation and dusting method (Patel et al., 1936) during rabi 2018, at Department of Oilseeds, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu to obtain 25 crosses.

The 25 F₁s along with their parents were studied in randomized block design with three replications and cultivated based on the basic package practice of groundnut during kharif 2019 at Department of Oilseeds, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu.

The F₁ plants were closely observed for various exclusive traits of their respective male parents and tagged as true F₁s. Observations were recorded on these true F₁s from each cross and their parents in each replication for eight quantitative traits viz., days to maturity, height of main axis, number of branches, number of matured pods, pod yield/plant, kernel yield/plant, shelling percentage and hundred pod weight. The recorded data was analyzed for L×T using the software TNAUSTAT statistical package.

The results are supported by the ratio of variance of dominance and variance of additive gene action which is less than unity for all traits whereas the value is more than one to that of height of the main axis, pod yield and kernel yield per plant. These traits show a greater SCA revealing a preponderance of additive gene action for all the traits except number of branches, number of matured pods, pod yield/plant, kernel yield/plant, shelling percentage and hundred pod weight. The recorded data was analyzed for L×T using the software TNAUSTAT statistical package.

| Source                  | Mean sum of squares |
|-------------------------|---------------------|
|                         | DM      | HMA     | NB      | NMP     | PY/P    | KY/P    | SP      | HPW     |
| Replication             | 2       | 0.106   | 8.65    | 2.02    | 0.26    | 0.106   | 0.59    | 0.76    | 4.58    |
| Crosses                 | 24      | 196.8*  | 104.5*  | 118.6*  | 418.1*  | 515.6*  | 241.1*  | 123.5*  | 653.2*  |
| Lines                   | 4       | 156.1*  | 274.9*  | 106.9*  | 114.3*  | 177.8*  | 617.7*  | 115.5*  | 164.9*  |
| Testers                 | 4       | 59.0*   | 337.3*  | 17.9*   | 147.8*  | 264.9*  | 111.5*  | 15.5*   | 441.3*  |
| L×T interaction         | 16      | 347.8*  | 433.4*  | 98.7*   | 155.9*  | 311.2*  | 168.2*  | 66.3*   | 469.9*  |
| Error                   | 48      | 42.6    | 10.7    | 101.3   | 29.3    | 44.9    | 19.8    | 12.4    | 23.14    |

\[ df - Degrees of freedom, DM - Days to Maturity, HMA - Height of main axis, NB - No. of branches, NMP - No. of matured pods, PY/P - Pod yield per plant, KY/P - Kernel yield per plant, SP - Shelling percentage, HPW - Hundred pod weight. \]

**RESULTS AND DISCUSSION**

**Genetic Variability among parents and hybrids**

The estimates of mean sum of squares (Table 1) due to crosses, lines, testers, line and tester interaction showed significant variation all the characters studied indicating the presence of significant variation among the genotypes as well as crosses studied. Considerable genetic variation for various traits including pod yield per plant have been reported by many workers (Golakia et al., 2005; Khote et al., 2009). This result further enabled the study of combining ability estimation among the parents and the crosses.

The magnitude of genetic variances is presented in the Table 2. The variances due to GCA and SCA are significant except for shelling percentage revealing the importance of both additive and non-additive gene action of the traits under study which is on par with the results reported by Trivikrama et al. (2017), in groundnut.

The result shows that the variance due to GCA is greater in most of the traits than that of SCA, indicating the preponderance of additive gene action for all the traits except number of branches, number of matured pods, pod yield/plant, kernel yield/plant, shelling percentage and hundred pod weight. These traits show a greater SCA revealing a dominant gene action. Similar kind of non-additive gene action was reported earlier for kernel yield/plant, pod yield/plant by Shoba et al. (2010).

The results are supported by the ratio of variance of dominance and variance of additive gene action which is less than unity for all traits whereas the value is more than one for height of main axis, pod yield and kernel yield per plant.
General and Specific Combining Ability Effects

The mean performance of parents and hybrids are important criteria for genotypic evaluation; however, the parents with high mean value may not transmit this characteristic to their hybrids. These parental and hybrid abilities are estimated in terms of GCA and SCA effects. The mean performances of parents and crosses are furnished in the Tables 3 and 4.

Among the parents Chico was the earliest in maturity while VRI 6 took the longest time to mature. VRI 3 recorded the maximum height for the main axis and the result is presented in the Table 5. For pod yield per plant the varieties ICGV 07222, VRI 8, Chico and ICGV 91114 were good combiners, VRI 6 and VRI 3 were average combiners and CO 7, GPBD 4, Gangapuri and ICGV 93468 were poor combiners. Similar classification of lines and testers were also done by Waghmode et al. (2017) in the genetic analysis of groundnut genotypes.

The crosses show significant variations among them for the traits studied. Out of 25 crosses studied the cross CO 7 X Chico, recorded the earliest maturity, the height of main axis was highest for the cross VRI 8 X Gangapuri, the number of branches was maximum in the cross ICGV 07222 X ICGV 91114 and the number of matured pods were high in the cross VRI 6 X Chico. The cross ICGV 07222 X Chico recorded the highest pod yield per plant. Kernel yield per plant and shelling percentage was high in the cross CO 7 X Chico while maximum hundred pod weight was observed by the cross VRI 8 X Gangapuri.

When the mean performance of pod yield per plant with significant specific combining ability effects (sca) is taken as criteria for the selection of elite cross the crosses in order as ICGV 07222 X Chico, CO 7 X Chico, ICGV 07222 X ICGV 91114, VRI 8 X VRI 3 and VRI 6 X ICGV 93468 could be selected.

In addition the cross CO 7 X Chico shows earliest maturity, high kernel yield per plant and shelling percentage with significant specific combining ability for all the important yield contributing traits in the preferred direction. The details of sca and gca effects of the superior crosses selected are furnished in the Table 6. The lines ICGV 07222 and VRI 8 and the testers Chico and ICGV 91114 are good combiners for pod yield. From the characterization of lines and testers the highest performing cross viz., ICGV 07222 X Chico is a product of good combiners showing the maximum heterosis for pod yield per plant. Interestingly the cross CO 7 X Chico is a hybrid of poor and good combiner
Table 4: Mean performance of cross combinations and sca effects.

| Crosses        | DM (Mean) | HMA (sca) | NB (Mean) | NMP (sca) | PY/P (Mean) | KY/P (sca) | SP (Mean) | HPW (sca) |
|----------------|-----------|-----------|-----------|-----------|-------------|------------|-----------|-----------|
| L₁ X T₁        | 107.0     | -0.08ₘ   | 26.0      | 2.97*     | 6.7         | 0.17ₘ      | 20.7      | 3.27*     |
| L₁ X T₂        | 101.3     | -4.35*    | 24.9      | 1.14*     | 8.3         | 0.71ₗ      | 29.0      | 3.87*     |
| L₁ X T₃        | 110.0     | 1.59*     | 23.2      | -2.50*    | 7.3         | 0.31ₘ      | 16.0      | 4.07*     |
| L₁ X T₄        | 107.7     | 0.45ₘ    | 25.7      | -1.87*    | 7.0         | -0.76ₘ     | 14.3      | -6.07*    |
| L₁ X T₅        | 109.0     | 2.39*     | 28.8      | 0.26ₘ    | 6.3         | -0.43ₘ     | 10.7      | -5.13*    |
| L₁ X T₆        | 109.7     | 1.25*     | 18.2      | -1.9ₗ   | 12.3        | -1.8ₗ      | 23.7      | -1.60*    |
| L₁ X T₇        | 104.7     | -2.01*    | 22.1      | 1.27ₘ    | 17.0        | 1.64ₗ      | 35.3      | 2.3ₗ      |
| L₁ X T₈        | 111.7     | 1.92*     | 23.9      | 1.1ₗ      | 13.7        | -1.0ₗ      | 17.0      | -2.8₀    |
| L₁ X T₉        | 105.0     | -3.8ₗ    | 23.9      | -0.7ₗ    | 17.7        | 2.1ₗ      | 30.7      | 2.₄₀    |
| L₁ X T₁₀       | 110.7     | 2.7₂*     | 25.8      | 0.2ₗ     | 13.7        | -0.8ₗ      | 23.3      | -0.₃ₗ    |
| L₁ X T₁₁       | 120.3     | 1.1ₗ     | 28.0      | 3.ₘₗ    | 6.0         | 0.0ₗ      | 26.0      | 1.ₗₗ    |
| L₁ X T₁₂       | 120.7     | 2.₉₂*    | 22.4      | -2.₅₀    | 5.7         | -1.₄ₗ      | 37.3      | 5.₃ₗ    |
| L₁ X T₁₃       | 121.3     | 0.₈₅ₗ   | 21.2      | -5.₆ₗ   | 6.₃         | -0.₁ₗ      | 9.₀      | -9.₈₀   |
| L₁ X T₁₄       | 118.0     | -1.₈₃ₗ  | 31.₄      | 2.₆ₗ      | 6.₃         | -0.₈ₗ      | 26.₀      | -1.₂ₗ    |
| L₁ X T₁₅       | 115.0     | -3.₆ₗ    | 31.₃      | 1.₆ₗ    | 8.₇         | 2.₄ₗ      | 26.7      | 4.₀ₗ    |
| L₁ X T₁₆       | 105.7     | -1.₂₁ₗ  | 25.₂      | -0.₇ₗ    | 9.₇         | 2.₃ₗ      | 21.₀      | 1.₀ₗ    |
| L₁ X T₁₇       | 107.7     | 2.₁₉*    | 27.₄      | 0.₇₁ₘ   | 7.₇         | -0.₈₃ₗ    | 2₆.₃      | -1.₄₀    |
| L₁ X T₁₈       | 106.0     | -2.₂₁ₗ  | 3₂.₇      | 4.₀ₗ    | 8.₃         | 0.₄ₗₘ    | 1₅.₃      | 0.₈₀ₗ   |
| L₁ X T₁₉       | 109.₃     | 2.₃₂*    | 2₉.₀      | -1.₅ₗ   | 7.₃         | -1.₂ₗₘ    | 2₉.₀      | -2.₃₃    |
| L₁ X T₁₀₀      | 105.₃     | -1.₀₈ₗ  | 2₉.₀      | -2.₄ₗ   | 7.₀         | -0.₆₃ₗ    | 2ₚ.₃      | 1.₉₃*   |
| L₁ X T₁₀₁      | 108.₇     | -1.₁₅ₗ  | 1₹.₂      | -4.₁₁ₗ  | 7.₃         | -0.₆₃ₗ    | 1₀.₇      | -4.₄₃*   |
| L₁ X T₁₀₂      | 109.₇     | 1.₂₇*    | 2₃.₄      | -2.₃₄ₗ  | 1₅.₃       | -0.₀₉ₗₘ   | 1₂.₇      | -1₀.₁₃*  |
| L₁ X T₁₀₃      | 109.₀     | -2.₁₅*  | 2₉.₀      | 2.₉₉ₗ   | 1₅.₃       | 0.₅₁ₗₘ    | 1₇.₃      | 7.₇₃*   |
| L₁ X T₁₀₄      | 1₁₂.₃     | 2.₃₉*    | 2₉.₃      | 1.₄₈ₗ   | 1₆.₃       | 0.₇₇ₗₘ    | 2₅.₃      | 7.₂₇*   |
| L₁ X T₁₀₅      | 1₀₉.₀     | -0.₃₅ₗ  | 2₉.₀      | 0.₂₅ₘₗ  | 1₄.₀       | -0.₅₆ₗₘ   | 1₃.₀      | -1.₀₂ₗ   |

DM: Days to Maturity, HMA – Height of main axis, NB – No. of branches, NMP – no. of matured pods, PY/P – Pod yield per plant, KY/P – Kernel yield per plant, SP – Shelling percentage, HPW – Hundred pod weight.
and the cross VRI 6 X ICGV 93468 is a product of average and poor combiner for pod yield, when both the crosses show the highest sca effects for the trait. Similar results were reported by Savithramma et al., 2010 in groundnut exhibiting significant sca effects with combinations of parents with low and high gca effects. Thus, crosses with high sca effects do not always involve parents with high GCA effects. It may be suggested that inter allelic interaction could be considered in such situations.

Heterosis is the process by which the performance of F₁s is superior to that of the mean of the crossed parents. The standard heterosis was calculated with CO 7 variety as check which is the most popular and preferred variety in recent years (Table 7). The traits height of the main axis, number of branches and number of matured pods exhibited a highest level heterosis while shelling percentage did not record a positive heterosis at all. Regarding the pod yield per plant a maximum of 26.83% of heterosis was observed in the cross ICGV 07222 X Chico. Boraiah et al. (2012) also reported significant heterosis of 28.21% for pod yield in the groundnut cross R-2001-2 x GPBD-5 and for the traits number of mature pods, total number of pods.

Among the superior crosses selected, the cross CO 7 X Chico recorded a significant heterosis for days to maturity, number of matured pods, pod yield and kernel yield per plant in the desired direction. Other crosses viz., ICGV 07222 X Chico, ICGV 07222 X ICGV 91114, VRI 8 X VRI 3 and VRI 6 X ICGV 93468 also showed significant heterosis for pod yield and kernel yield per plant and recorded considerably good performances.

**Gene action and contribution to the total variance**

The preponderance of non-additive gene action for height of main axis pod yield and kernel yield per plant indicate that the selection of superior plants for these traits should postponed to later generation. These traits could be improved by selection among the recombinants of the segregating population. However the traits viz., days to maturity, number of branches, number of matured pods, shelling percentage and hundred pods weight are governed by additive gene action. In the study of L×T analysis Ganesan et al. (2010), reported similar suggestions for the improvement of pod yield in groundnut.

In a combining ability analysis by John et al. (2014) in groundnut similar results of predominantly additive gene effects for days to 50 per cent flowering, days to maturity, harvest index and pod yield per plant and predominantly non additive gene effects for specific leaf area and transpiration rate was reported.

**Table 5:** Summary of general combining ability effect of the parent for different character in groundnut.

| Parents   | DM | HMA | NB | NMP | PY/P | KY/P | SP   | HPW  |
|-----------|----|-----|----|-----|------|------|------|------|
| CO 7      | G  | P   | P  | P   | P    | P    | P    | G    |
| ICGV 07222| G  | P   | G  | G   | G    | G    | P    | P    |
| VRI 6     | P  | G   | P  | G   | A    | G    | G    | P    |
| VRI 8     | G  | G   | P  | A   | G    | G    | G    | G    |
| GPBD 4    | A  | A   | G  | A   | A    | P    | P    | G    |

**Lines**

| Testers   | DM | HMA | NB | NMP | PY/P | KY/P | SP   | HPW  |
|-----------|----|-----|----|-----|------|------|------|------|
| VRI 3     | A  | P   | A  | A   | A    | P    | P    | G    |
| CHICO     | G  | P   | A  | G   | G    | G    | P    | G    |
| GANGAPURI | P  | A   | A  | P   | P    | G    | G    | P    |
| ICGV 91114| A  | G   | A  | G   | G    | G    | P    | P    |
| ICGV 93468| A  | G   | A  | P   | P    | P    | G    | P    |

**Testers**

DM- Days to Maturity, HMA – Height of main axis, NB – No. of branches, NMP – no. of matured pods, PY/P – Pod yield per plant, KY/P – Kernel yield per plant, SP – Shelling percentage, HPW – Hundred pod weight.

G = Good parent having significant GCA effects in desirable direction; A = Average parent having either positive or negative but non-significant GCA effects; P = Poor parent having significant GCA effects in undesirable direction.

**Table 6:** Promising crosses based on specific combining ability in groundnut.

| Trait          | Crosses               | sca effect | GCA effect class of parents |
|----------------|-----------------------|------------|----------------------------|
|                | Line                  | Tester     |
| Pod yield per plant | ICGV 07222 X Chico  | 4.64 *     | G                         | G |
|                 | CO 7 X Chico          | 10.66*     | P                         | G |
|                 | ICGV 07222 X ICGV 91114| 3.34 *     | G                         | G |
|                 | VRI 8 X VRI 3         | 3.83 *     | G                         | A |
|                 | VRI 6 X ICGV 93468    | 10.26 *    | A                         | P |

G = Good parent having significant GCA effects in desirable direction; A = Average parent having either positive or negative but non-significant GCA effects; P = Poor parent having significant GCA effects in undesirable direction.
Choice of parents could be made considering the per se performance and gca effects. In doing so, the parents ICGV 07222, VRI 8, Chico and ICGV 91114 showed considerable values for pod and kernel yield with highest positive general combining ability. Thus these parents could be used in breeding programs as good combiners to incur better results. The contribution of lines to total variance than the testers for most of the traits under study including pod yield per plant indicates the correct selection of lines in the crossing program. The cross ICGV 07222 X Chico recorded the maximum pod and kernel yield per plant with 26.83% heterosis and could be advanced to further selection to obtain elite segregants.

CONCLUSION

Thus, from the study the traits pod and kernel yield per plant in groundnut showed the preponderance of non-additive gene action suggesting that selection for these traits should be carried out in the later generations of the recombinants. The varieties ICGV 07222, VRI 8, Chico and ICGV 91114 are promising combiners to be used as parent in various breeding programs. The cross ICGV 07222 X Chico is suggested to be forwarded to obtain superior cultivars in the later generations. A maximum of 27% of heterosis was observed for pod yield in groundnut. The improvement of groundnut cultivars could be achieved through pedigree breeding involving crossing of superior parents followed by selection in the recombinants.

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