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Research Article

Understanding combining ability, heterosis and relationships of pod yield and yield contributing traits in groundnut (*Arachis hypogaea* L.)

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Abstract

The study was conducted to estimate the magnitude of heterosis and combining ability effects in groundnut for yield attributing traits. Fifty-six F_1 hybrids developed through Line × Tester mating fashion were evaluated along with the parents in RCBD with two replicates during *kharif*-2022. Analysis of variance showed significant differences among genotypes for all the studied traits. The hybrids K 6 × ICGV 15402, VRI 10 × ICGV 15402, VRI 10 × ICGV 15426 exhibited positive heterosis for traits number of primary branches, pods/plant, kernel yield, 100 kernel weight and shelling percentage. Significant negative heterosis was observed for plant height in these crosses namely, CO 7 × ICGV 15412, VRI 7 × ICGV 15408 and VRI 8 × ICGV 15402. The study recorded significantly higher SCA variances compared to GCA variances, indicating a predominant role of non-additive gene action for all the traits studied. Line VRI 7 showed significant gca effects for all the traits except shelling % and hundred kernel weight and was identified as a best general combiner. The hybrids VRI 8 × ICGV15426 and VRI 7 × ICGV15402 revealed superior performance in terms of pod yield per plant. Notably, the cross VRI 7 × ICGV15402 exhibited outstanding performance across all traits, highlighting the prominence of a parent with strong SCA. Pod yield was significantly correlated with kernel yield/plant and sound mature kernel. Path analysis highlighted the direct and indirect effects of traits on pod yield, emphasizing the importance of kernel yield and sound mature kernel. This study underscores the utility of heterosis breeding in improving groundnut for enhanced yield and suggests specific parent combinations for future breeding.

Keywords: Combining ability, groundnut, gene action, heterosis, line × tester

INTRODUCTION

Groundnut (*Arachis hypogea* L.), known as the "Wonder Legume," holds importance due to its nutritional, medicinal, and fodder values. It serves as a rich source of edible oil, high-quality protein, fat, and carbohydrates. In India, it is the primary oilseed crop, prominently cultivated in states like Tamil Nadu, Andhra Pradesh, Gujarat, Karnataka, and Maharashtra (Shendekar *et al*., 2023). The introduction of new varieties with improved agronomic traits has been pivotal in enhancing food production (Madhu *et al*., 2023(a)). Increased groundnut pod yield can be achieved through addressing physiological constraints and implementing scientific interventions (Harisudan and Subrahmaniyan, 2020). Traditionally, groundnut breeding programs have focused on hybridization followed by selection in segregating generations. Despite being predominantly self-pollinated, the understanding of heterosis in groundnut has evolved, serving as a basis for genetic diversity and guiding the selection of superior parents for developing F_1 hybrids to exploit hybrid vigour (Banoth *et al*., 2023(a); Banoth *et al*., 2021(a)). This approach enriches the gene pool and contributes to ongoing breeding efforts for improved groundnut varieties. Heterosis in the F_1 generation, expressed through superiority over the better/mid /standard parent, holds significant relevance not only in cross-pollinated crops but also in self-pollinated ones. Heterotic crosses aid breeders in selecting appropriate combinations that can yield desirable transgressive segregants in subsequent generations (Madhu *et al*., 2023(a); Arunachalam *et al*., 1984). The occurrence of heterosis in groundnut was first noted by Shull (1948), and since then, various studies have documented heterosis for yield and its components in groundnut (Deshmukh *et al*., 1985; Dwivedi *et al*., 1994). Evidence suggests that heterosis in groundnut correlates with parental genetic diversity. Promising F_1 hybrids displaying desirable traits can be advanced to obtain transgressive segregants. The combining ability analysis quickly reveals the genetic basis of traits and guides the selection of superior parents, leading to improved progeny. Understanding how gene action effecting yield and its components is crucial for selecting the appropriate breeding methods to isolate desired traits in future generations.

Line (L) × Tester (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). The 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. The present study investigates the magnitude of heterosis and combining ability effects for pod yield and other component traits. In addition, correlation and path analysis were carried to find the extent and strength of relationship among traits.

MATERIALS AND METHODS

Seven lines and eight testers were chosen based on their distinct quantitative traits, as detailed in **Table 1**. Hybridization was done in Line × Tester (L × T) fashion during the Summer 2021 season at the Regional Research Station, Vridhachalam, India, resulting in the development of 56 F_1 hybrids. Assessment of performance of hybrids in comparison with parents and checks was done during *Kharif* 2022. The genotypes were evaluated in a randomised block design (RBD) with two replications and each genotype was raised in two rows of four meter length with a spacing of 30 × 10 cm between rows and plants respectively. Observations were recorded on 12 traits namely plant height (PH, cm), number of primary branches per plant (NPB), number of secondary branches per plant (NSB), number of mature pods per plant (NMP), number of immature pods per plant (NIMP), pod yield per plant (PYP, g), kernel yield per plant (KYP, g), shelling percentage (S%), hundred pod weight (HPW, g) and hundred kernel weight (HKW, g) and sound mature kernel percentage (SMK%). Analysis of Variance (ANOVA) was calculated according to Panse and Sukhatme (1962), using the mean genotypic values. The L × T analysis was performed to estimate the combining ability effects as suggested by Kempthorne (1957), using TNAUSTAT statistical package (*v 2.0.1*) (Manivannan, 2014). Heterosis over the better-parent was calculated following the method proposed by Fonseca and Patterson (1968), while standard heterosis was determined using VRI 8 as the standard check, as per Meredith and Bridge (1972). The correlation and path coefficient analysis were carried out using “Correplot” and “Phylopath” R-packages (v.4.2.1), respectively.

RESULTS AND DISCUSSION

The ANOVA revealed significant genotypic variations ($P \le 0.05$) for all the characters examined (**Table 2**). Studies have documented significant genetic variation between hybrids for a variety of characteristics, indicating potential for improved selection outcomes (Golakia *et al.,* 2005; Khote *et al.,* 2009; Banoth *et al.,* 2021(b); Madhu *et al.,* 2023(a); Banoth *et al*., 2023; Madhu *et al.,* 2024). Significant variances were observed among hybrids and parents for all the characters, and also the variances due to hybrids *vs* parents had significance for all characters indicating potential for improved selection outcomes. Considerable genetic variation for various traits including pod yield per plant have been reported by many workers (Rashid *et al.,* 2007; Khote *et al*., 2009; Madhu *et al*., 2023 (a)).

ANOVA for combining ability (**Table 2**) indicated the presence of significant differences among the lines and testers for all the characters studied. The significant variance of L × T interaction indicated the importance of SCA (Banoth *et al.,* 2021). The mean squares due to lines were of a larger magnitude than those of testers and L × T for all the characters indicating greater diversity among the lines for combining ability. The magnitude of SCA variances was much greater than those of GCA variances for all the characters, which indicated the preponderance of non-additive gene action for all the characters (Madhu *et al*., 2023). Similar kind of non-additive gene action was reported earlier for kernel yield/plant, pod yield/plant by Shoba *et al*. (2010). Hence improvement of yield related characters could be accomplished by selection at later generations. The role of non-additive gene action for these characters have been reported by Sprague and

Table 1. List of parents used in the study.

Parents	Feature	Source
VRI 7	Moderately resistant to late leaf spot and rust diseases, moderately resistant to leaf miner.	RRS, Vridhachalam
VRI 8	Moderately resistant to sucking pest (Jassids and thrips) moderately resistant to LLS and rust.	
VRI 9	Moderately resistant to sucking pests and defoliators moderately resistant to LLS and rust.	
VRI 10	Moderately resistant to sucking pests and defoliators moderately resistant to LLS and rust.	
K 6	Tolerant to late leaf spot.	RARS-Kadiri
GG 7	Early maturity and Tolerant to late leaf spot.	GAU, Gujarat
CO 7	Tolerant to major foliar diseases viz., late leaf spot and rust.	TNAU Coimbatore
ICGV 15402, ICGV 15412, ICGV 15432, ICGV 15427, ICGV 15426, ICGV 15408, ICGV 15410	These parents have 15 days fresh seed dormancy	ICRISAT, Hyderabad.

Table 2. ANOVA of mean squares of RCBD and combining ability for parents and hybrids for yield and its component characters in groundnut.

Source	df	PH	NPB	NSB	NMP	NIMP	PYP	KYP	S	HPW	HKW
ANOVA Mean squares of RCBD											
Replication	1	21.45	0.5454	0.5088	0.1363	0.262	0.183	0.0057	8.28	17.39	5.095
Hybrids	55	59.289**	1.7252**	4.8084**	11.4609**	2.926**	12.66**	5.833**	54.1013**	372.71**	48.44**
Parents	14	104.74**	1.8150**	4.3696**	11.928**	1.7379**	15.00**	9.208**	81.7249**	207.52**	52.80**
Hybrids vs Parents	1	397.71**	8.1423**	1.5136**	94.8100**	3.7522**	7.31**	7.30**	20.9793**	48.7221**	361.30**
Error	70	5.3132	0.1366	0.6039	1.855	0.332	1.406	1.013	5.3976	29.4519	5.0427
ANOVA Mean squares of L × T analysis											
Replication	1	14.42	0.6151	0.5022	0.8229	0.3004	0.280	0.0322	15.9	60.03	17.92
Line	6	148.49**	5.7534**	25.88**	11.4609**	8.31**	55.0075**	23.80**	196.84**	627.82**	225.3**
Tester	7	103.19**	0.3309**	1.9040**	24.9951**	2.73**	11.2753**	5.60**	22.91**	353.80**	39.97**
L x T	42	39.2280**	1.1995**	2.5236**	9.1517**	2.189**	6.8462**	3.3043**	38.90**	196.56**	24.58**
Error	55	5.3132	0.1522	0.6011	2.1994	0.3947	1.6478	1.1453	5.890	33.377	5.549
GCA		0.4375	0.0084	0.0536	0.0504	0.0161	0.1269	0.0552	0.3314	3.8415	0.5204
SCA		16.705	0.5236	0.9612	3.4761	0.8973	2.5992	1.0795	16.5084	81.5952	9.5161
GCA/SCA		0.026	0.0160	0.0557	0.014	0.0179	0.0488	0.0511	0.0200	0.0470	0.0546

*, ** significant at 5% and 1% levels, respectively. PH-Plant height (cm), NPB -Number of primary branches per plant, NSB-Number of secondary branches per plant, NMP- Number of mature pods per plant, NIMP- Number of immature pods for plant, PYP- Pod yield per plant (g), KYP- Kernel yield per plant (g), S%- Shelling percentage, HPW-Hundred pod weight (g), HKW-Hundred kernel weight (g).

Tatum, (1942), Jayalakshmi *et al*. (2002), Yadav *et al*. (2006), Manivannan *et al*. (2008), Rekha *et al.* (2009), Ganesan *et al*. (2010), Mothilal and Ezhil (2010). Studies also reported that dominance effects play a significant role in these traits under water stress conditions (Savithramma *et al.* 2010; Sangeetha *et al*. 2021).

The *per se* performance of parents for yield and its component characters are presented in **(Table 3)** and are compared with general mean. Based on performance *per se*, the parent VRI 8 recorded higher mean pod weight per plant and kernel weight per plant. Genotype ICGV 15388 recorded higher mean for shelling percentage, 100 pod weight per plant and 100 kernel weight per plant. Line VRI 9 recorded higher mean for number of pods per plant whereas for plant height ICGV 15410 recorded the high mean. Hence these parents were considered as more superior than other parents.

The estimates of gca effect (**Table 4**) showed that among the lines, VRI 7 was found to be a superior as it showed significant and positive gca effect for number of pods per plant, number of primary and secondary branches per plant, pod weight per plant, kernel weight

Table 3. Genotypes mean performance and rages of heterosis for yield and yield contributing traits

Traits	Parents		Hybrids		Range of Heterosis %		Number of crosses with significant heterosis			
	Mean (±SE)	Range	Mean (± SE)	Range	Heterobeltiosis	Standard heterosis	Heterobeltiosis		Standard heterosis	
							+^{ve}	-^{ve}	+^{ve}	-^{ve}
PH (cm)	55.25±1.23	46.02-72.95	51.5±1.52	41.80-60.80	-38.93-11.90	-23.30-11.60	25	15	19	17
NPB	4.24±0.51	2.26-6.38	4.84±0.71	3.80-7.40	-26.69-83.83	-3.80-87.34	27	12	38	12
NSB	3.15±0.12	1.81-7.21	3.41±0.35	0.50-7.15	-60.76-102.00	-73.77-126.23	18	10	32	10
NMP	16.82±1.27	12.95-20.48	18.76±1.36	12.65-36.55	-25.79-53.51	-41.34-23.20	20	14	16	19
NIMP	3.05±0.06	1.67-4.74	3.45±0.20	1.95-10.30	-45.07-82.35	-58.95-116.84	18	18	2	14
PYP (g)	19.44±1.33	12.58-23.80	16.10±1.42	8.45-43.35	-52.71-56.67	-48.32-74.26	12	11	24	16
KYP (g)	14.81±2.36	9.79-18.81	14.59±1.50	8.80-34.00	-23.10-22.84	-59.35-18.61	18	15	12	13
S %	75.48±6.78	58.73-84.50	74.53±5.69	82.45-56.35	-26.24-22.84	-30.52-11.34	13	10	14	12
HPW (g)	114.65± 10.36	127.71-88.37	99.38±9.51	49.70-131.25	-59.35-13.05	-61.56-8.76	15	13	18	17
HKW(g)	46.40±3.69	37.08-54.16	43.74±5.36	23.15-54.25	-59.84-9.53	- 63.47-19.7	16	15	22	10
SMK	78.40±6.01	76.34-79.95	55.12±4.77	23.60-79.60	-5.33-5.36	-7.76-9.58	15	12	26	15

PH-Plant height (cm), NPB -Number of primary branches per plant, NSB-Number of secondary branches per plant, NMP- Number of mature pods per plant, NIMP- Number of immature pods for plant, PYP- Pod yield per plant (g), KYP- Kernel yield per plant (g), S%- Shelling percentage, HPW-Hundred pod weight (g), HKW-Hundred kernel weight (g).

Table 4. Estimates of general combining ability (gca) effects for yield and its component characters in groundnut

Parents	PH	NPB	NSB	NMP	NIMP	PYP	KYP	S	HPW	HKW
Lines										
VRI 7	3.93**	0.54**	2.23**	1.62**	0.33*	1.26**	0.87**	-0.78	-1.39	-1.22*
VRI 8	0.23	-0.24 *	1.14**	1.41**	1.27**	1.99**	1.41**	-0.01	3.59*	0.91
VRI 9	0.10	1.08**	-0.52**	0.33	-0.60**	0.81*	0.71**	-0.41	-3.63*	1.33*
GG 7	-2.34**	-0.42**	-1.20**	-1.81**	-0.62**	-0.67*	0.05	3.56**	10.50**	5.58**
CO 7	-5.19**	-0.03	-0.19	-0.38	0.33*	1.31**	-0.15	-6.81**	12.12**	0.20
K 6	2.73**	-0.56**	-1.29**	-1.10**	-0.74**	-1.61**	-0.59*	3.74**	-3.49*	0.23
VRI 10	0.54	-0.37**	-0.17	-0.08	0.03	-3.11**	-2.30**	-0.13	-17.69**	-7.02**
Testers										
ICGV 15402	1.21	-0.15	-0.44*	1.50**	-0.16	-0.52	-0.30	0.21	-9.89**	-3.57**
ICGV 15412	-3.03 **	0.01	0.02	-1.43**	0.99**	-1.44**	-0.91**	0.92	-2.20	0.56
ICGV 15432	-2.17 **	-0.01	-0.35	-0.09	-0.52**	0.26	-0.25	-2.94**	1.19	-0.55
ICGV 15427	5.37 **	-0.09	0.05	0.23	0.14	1.13**	0.88**	0.70	7.27**	1.86**
ICGV 15426	1.65 *	0.20	-0.30	0.55	-0.09	0.53	0.27	-0.57	-1.74	-0.79
ICGV 15408	-0.02	0.26*	0.62**	-1.39**	-0.07	-1.04**	-0.68*	0.68	3.99*	1.39*
ICGV 15410	-1.35*	-0.16	0.33	0.49	-0.20	0.65	0.62*	0.78	0.96	0.56
ICGV 15388	-1.67*	-0.06	0.07	0.14	-0.09	0.42	0.36	0.21	0.41	0.55
S.E. (Lines)	0.602	0.0975	0.1938	0.3708	0.1571	0.3209	0.2675	0.6067	1.4443	0.5889
S.E. (Testers)	0.644	0.1043	0.2072	0.3964	0.1679	0.3431	0.2860	0.6486	1.5441	0.6296

*, ** significant at 5% and 1% levels, respectively. PH-Plant height (cm), NPB -Number of primary branches per plant, NSB-Number of secondary branches per plant, NMP- Number of mature pods per plant, NIMP- Number of immature pods for plant, PYP- Pod yield per plant (g), KYP- Kernel yield per plant (g), S%- Shelling percentage, HPW-Hundred pod weight (g), HKW-Hundred kernel weight (g).

per plant. The line GG 7 was a good general combiner for shelling percentage, 100 pod weight per plant and 100 kernel weight per plant. While CO 7 was a good general combiner for plant height. Among the testers, ICGV 15427 and ICGV 15402 registered significant positive gca effect for pod weight per plant, kernel weight per plant, 100 pod weight per plant and 100 kernel weight per plant and for number of pods per plant and identified as good general combiners. Since, high gca effect is attributed to additive gene actions, these parents could be used in breeding programme for yield improvement through pedigree breeding. Selection for these traits should be based on evaluations across multiple environments (Manivannan *et al*. (2008). Similar results have been reported by Vishnuvardhan (2011), Waghmode *et al*. (2017), Onyia (2011), Hariprasanna *et al.* (2008) and Shoba *et al.* (2010) in the genetic analysis of groundnut genotypes.

Based on gca effects, the parents VRI 7, GG 7 CO 7, ICGV 15427 and ICGV 15402 were identified as best combiners for yield traits. The *per se* performance of hybrids for yield and its component characters are presented in **Table 3** and combining ability effects of hybrids are furnished in **Table 5**. The crosses VRI 8 × ICGV 15426, VRI 9 × ICGV 15426, VRI 7 × ICGV 15410, VRI 7 ×ICGV 15402, VRI 8 × ICGV 15412, VRI 8 × ICGV 15408 and GG 7 × ICGV 15427 manifested higher *per se* performance for plant height, number of primary and secondary branches per plant, number of mature pods per plant, number of immature pods for plant, shelling percentage, and hundred kernel weight respectively. This may be due to more parental contributions of favourable alleles from any or both parents in progenies based on the pod yield per plant, kernel yield per plant, hundred pod weight, the cross VRI 8 × ICGV 15427 is considered as desirable crosses. Among the 56 crosses, 20 were ranked as top crosses for one or more characters (**Table 5**). However, none of these crosses was found desirable simultaneously for all the characters *i.e.,* different crosses expressed significant sca effects for different characters. However, the cross VRI 7 × ICGV 15402 recorded significant sca effects for number of primary branches per plant, number of mature pods per plant, number of immature pods, pod yield per plant, kernel yield per plant. The cross VRI 7 x ICGV 15402 exhibited superior *per se* performance and had one of the parents with good GCA. Hence, in this cross selection can be made in early generation itself. Similar results were reported by Ganesan *et al.* (2010), Mothilal and Ezhil (2010), Savithramma *et al.* (2010).

The range of standard heterosis and the frequency of hybrids with desired heterosis over superior parents and standard check are tabulated in **Table 3**. Three of the most promising cross combinations, as well as both heterobeltiosis and standard heterosis for several traits are tabulated in **Table 6**. Positive heterosis was considered beneficial for yield contributing features, but negative heterosis was considered as beneficial for plant height. Standard heterosis for plant height ranged from -23.3% to 11.6% across different crosses, with CO 7 × ICGV15412 (-23.3%), VRI 7 × ICGV 15408 (-18.18%), and VRI 8 × ICGV 15402 (-19.01%) exhibiting high negative heterosis compared to the better parent. Significant negative heterosis for plant height was observed in 25 and 15 hybrids based on superior parent and standard check, respectively. Significant positive heterosis for the number of main branches/plants was detected in 27 and 38 hybrids relative to the superior parent and standard check. Notably, CO 7 × ICGV 15408 (83.33%), VRI 9 × ICGV 15426 (42.31%), and VRI 9 × ICGV 15432 (41.35%) displayed high heterobeltiosis for this trait.

The number of pods/plants is a crucial determinant of yield, favouring hybrids with positive heterosis for enhanced productivity. Among the 56 hybrids assessed, 20 and 14 crosses exhibited significant positive heterosis compared to the superior parent and standard check, respectively, which aligned with findings of Sharma and Gupta (2010). Notably, K 6 × ICGV 15402 (55.64%), VRI 10 × ICGV 15402 (47.51%), and VRI 10 × ICGV 15426 (40.50%) displayed notable positive standard heterosis for pod yield/plant surpassing the standard check. Standard heterosis ranged from -48.32% to 74.26% over the check. This is consistent with observations by Jivani *et al*., (2008), and Sharma and Gupta (2010) for pod yield and its contributing factors. The range of heterosis for kernel yield/plant was between -59.35% and 18.61% above the check. Significant positive heterosis for kernel yield/plant was evident in 18 hybrids compared to the better parent and 15 hybrids compared to the standard check. For 100 kernel weight, standard heterosis ranged from -63.47% to 19.7% above the check, with VRI 10 × ICGV 15402 displaying the highest positive standard heterosis (14.65%). Moreover, 16 hybrids surpassed the better parent, and 15 hybrids exceeded the standard check in positive heterosis for 100 kernel weight. The hybrid VRI 10 × ICGV 15426 exhibited the highest positive standard heterosis (9.50%) for shelling percentage, surpassing the standard check. Heterosis estimates for shelling percentage were substantial and positive in 13 hybrids over the better parent and 10 hybrids over the standard check. It is consistent with Gor *et al*., (2012) and John *et al*., (2014).

The magnitude of heterosis for sound mature kernel ranged from -7.76% to 9.58%, with VRI 10 × ICGV 15402 showing the highest positive heterosis (8.89%) compared to the standard check. Developing a breeding program focusing on agro-economic aspects could lead to improvements in complex traits like pod yield. Hybrid breeding strategies prove beneficial in identifying highly heterotic cross combinations. Three hybrids, namely K 6 × ICGV 15402 (55.64%), VRI 10 × ICGV 15402 (47.51%), and VRI 10 × ICGV 15426 (40.50%), outperformed both their respective superior parents and the standard check in terms of pod yield/plant. Evaluation of these crosses

Table 5. Estimates of specific combining ability effects for yield and its component characters in groundnut.

Hybrids	PH	NPB	NSB	NMP	NIMP	PYP	KYP	S	HPW	HKW
VRI 7 X ICGV 15402	-1.84	1.52**	0.95	2.86**	1.04*	2.67**	2.22**	0.48	-1.37	0.36
VRI 7 X ICGV 15412	-1.20	-0.04	-0.21	1.09	-0.72	0.34	-0.21	-3.08	-3.36	-3.62*
VRI 7 X ICGV 15432	6.59**	0.38	-0.64	0.71	0.64	0.89	0.47	-0.62	0.85	-0.51
VRI 7 X ICGV 15427	0.46	-0.74**	-1.94**	0.68	0.64	-1.83	-0.21	7.18**	-17.38**	-2.07
VRI 7 X ICGV 15426	0.07	0.27	1.56**	0.36	-0.03	0.02	0.76	4.65**	-1.47	1.63
VRI 7 X ICGV 15408	5.59**	-0.54	-0.90	-3.59**	1.46**	-2.71	-2.50	-3.29	5.50	0.75
VRI 7 X ICGV 15410	-9.18**	-0.72*	1.18*	-2.28*	-0.93*	-0.90	-0.90	-1.20	8.34*	2.67
VRI 7 X ICGV 15388	0.44	-0.12	-0.01	0.17	0.82	1.53	0.37	-4.12*	8.89*	0.79
VRI 8 X ICGV 15402	2.10	-0.19	-0.45	-1.23	-1.46**	1.53	0.58	-3.44*	14.39**	3.58*
VRI 8 X ICGV 15412	-4.26*	0.24	-1.52**	-1.45	4.59**	-1.24	-0.66	1.40	4.81	1.80
VRI 8 X ICGV 15432	-3.52*	0.11	0.16	2.12*	-0.65	1.46	0.03	-5.94**	-3.09	-4.54**
VRI 8 X ICGV 15427	0.79	-0.01	0.81	1.00	-0.71	4.78**	2.55**	-5.74**	19.28**	4.95**
VRI 8 X ICGV 15426	7.76**	-0.49	-0.74	1.02	-0.03	-1.66	-0.49	4.04*	-13.81**	-3.30*
VRI 8 X ICGV 15408	-2.52	-0.30	-0.06	-1.83	-0.45	-3.24**	-1.39	7.24**	-11.41**	-0.03
VRI 8 X ICGV 15410	1.37	1.06**	-0.67	0.58	-0.82	-1.48	-0.89	0.59	-12.20**	-3.91
VRI 8 X ICGV 15388	-1.72	-0.44	2.48**	-0.22	-0.48	-0.15	0.27	1.86	1.75	1.46
VRI 9 X ICGV 15402	-1.66	-0.37	1.10*	-1.29	0.51	0.52	0.63	2.19	9.72*	3.96*
VRI 9 X ICGV 15412	-1.32	-0.58*	1.19*	-0.57	-0.64	-0.01	0.39	3.08	-6.72	3.33
VRI 9 X ICGV 15432	-3.78*	1.44**	0.51	-1.05	-0.38	-1.51	-1.67*	-3.96*	-8.86*	-3.31
VRI 9 X ICGV 15427	3.63*	-0.77**	-0.69	2.33*	0.56	0.72	0.90	1.55	4.46	-2.57
VRI 9 X ICGV 15426	5.40**	1.28**	-0.44	-1.59	-0.51	-0.48	-0.44	-0.83	2.07	2.93
VRI 9 X ICGV 15408	-3.08	0.03	-0.50	2.95**	-0.23	1.79	1.01	-1.83	0.49	-4.10
VRI 9 X ICGV 15410	6.65**	0.04	0.23	0.06	0.20	-0.15	0.11	1.27	2.22	0.17
VRI 9 X ICGV 15388	-5.83**	-1.06**	-1.14*	-0.84	0.49	-0.87	-0.93	-1.46	-3.38	-0.41
GG 7 X ICGV 15402	0.08	-0.37	-0.16	-0.60	-0.26	0.75	0.60	0.89	2.99	1.51
GG 7 X ICGV 15412	1.77	0.62*	0.17	-1.72	-1.02*	-1.38	-1.09	0.13	8.45*	2.38
GG 7 X ICGV 15432	0.51	-0.41	-1.36*	-0.81	-0.16	-0.23	0.10	1.74	6.21	2.74
GG 7 X ICGV 15427	-4.39*	-0.27	-0.21	-0.48	0.69	-0.15	0.27	1.50	1.98	3.08
GG 7 X ICGV 15426	-0.07	-0.22	2.04**	1.40	0.12	-0.20	0.33	2.77	-11.76**	-3.37*
GG 7 X ICGV 15408	4.31*	-0.43	0.08	0.84	0.29	0.92	0.08	-3.98*	1.41	-1.05
GG 7 X ICGV 15410	-0.56	-0.36	-0.74	0.31	0.57	-0.02	0.08	0.77	-4.16	-0.93
GG 7 X ICGV 15388	-1.64	-1.44**	0.17	1.06	-0.23	0.31	-0.36	-3.81*	-5.11	-4.36*
CO 7 X ICGV 15402	5.13**	-0.01	-1.67**	-1.94	0.44	-0.28	0.50	4.31*	7.42	5.44**
CO 7 X ICGV 15412	6.07**	-0.17	0.47	4.04**	-1.02*	1.84*	-1.51*	0.50	-12.92**	-4.79**
CO 7 X ICGV 15432	-1.99	-100**	-0.86	-0.24	-1.26**	-1.21	0.55	8.56**	-5.41	2.37
CO 7 X ICGV 15427	2.11	0.84**	1.49**	-0.82	0.29	0.12	-1.53	-9.69**	6.21	-2.74
CO 7 X ICGV 15426	-5.32**	-0.86**	-0.76	0.01	0.67	1.82*	-0.67	-10.81**	13.22**	-2.19
CO 7 X ICGV 15408	-2.54	2.09**	0.82	-0.39	-1.09*	-0.76	0.43	5.79**	-2.86	2.88
CO 7 X ICGV 15410	-2.61	-0.15	1.51**	0.27	-0.03	0.95	0.63	-0.41	3.72	1.40
CO 7 X ICGV 15388	-0.84	-0.75**	-0.98	-0.93	-0.18	-2.47**	-1.41	1.76	-9.38	-2.38
K 6 XICGV 15402	0.10	-0.22	-0.38	-4.72**	-0.35	-4.12**	-3.92	-6.59	-4.82	-4.85**
K 6 X ICGV 15412	2.04	0.51	0.01	1.16	-0.71	2.26*	1.45	-1.60	10.84**	2.37
K 6 X ICGV 15432	3.43*	0.13	1.28*	-1.18	0.36	-1.09	-0.52	2.51	3.25	1.93
K 6 X ICGV 15427	1.39	0.17	0.48	-0.30	-0.55	-1.07	-0.39	2.66	-6.63	0.02
K 6 X ICGV 15426	-9.04**	-0.37	-1.02	-0.22	0.13	-0.46	0.12	3.24	-0.02	1.32
K 6 X ICGV 15408	0.68	-0.53	-0.63	1.42	1.06*	1.96*	1.11	-2.11	1.85	0.15
K 6 X ICGV 15410	-2.63	0.02	-0.65	2.49*	0.59	1.37	0.76	-1.81	-6.06	-3.03
K 6 X ICGV 15388	4.03*	0.33	0.91	1.34	-0.52	1.15	1.38	3.71*	1.59	2.08
VRI 10 X ICGV 15402	-3.90*	0.36	0.60	6.91**	0.08	-1.07	-0.61	2.18	-28.32**	-10.00**
VRI 10 X ICGV 15412	-3.11	-0.58*	-0.11	-2.56*	-0.48	-1.79	-1.39	-0.43	-1.11	-1.48
VRI 10 X ICGV 15432	-1.23	-0.65*	0.91	0.46	1.44**	1.71	1.04	-2.23	7.05	1.33
VRI 10 X ICGV 15427	-3.07	0.78**	0.06	-2.42*	-0.92*	-2.57**	-1.59	2.53	-7.93	-0.68
VRI 10 X ICGV 15426	1.20	0.39	-0.64	-0.99	-0.34	0.94	0.38	-3.05	11.78**	2.97
VRI 10 X ICGV 15408	-2.43	-0.32	1.20*	0.61	-0.31	2.06*	1.27	-1.84	4.75	1.40
VRI 10 X ICGV 15410	6.96**	0.15	-0.87	-1.43	0.42	0.22	0.22	0.80	8.14*	3.62*
VRI 10 X ICGV 15388	5.57**	0.60*	-1.16*	-0.58	0.11	0.50	0.68	2.08	5.64	2.83

PH-Plant height (cm), NPB -Number of primary branches per plant, NSB-Number of secondary branches per plant, NMP- Number of mature pods per plant, NIMP- Number of immature pods for plant, PYP- Pod yield per plant (g), KYP- Kernel yield per plant (g), S%-Shelling percentage, HPW-Hundred pod weight (g), HKW-Hundred kernel weight (g).

revealed significant characteristics across various yield-related traits. For instance, VRI 10 × ICGV 15402 exhibited positive heterotic effects for multiple traits including plant height, pod yield/plant and kernel yield/plant. Similarly, K 6 × ICGV 15402 and VRI 10 × ICGV 15426 displayed favourable heterotic impacts on several traits associated with pod yield. These findings are consistent with previous studies by Gor *et al*., (2012), Boraiah *et al*., (2012), John *et al*., (2014), Azad *et al*., (2014), and John *et al*., (2012), which have demonstrated diverse heterotic effects across different characters.

The correlation coefficients depicted in **Fig. 1,** illustrates significant positive associations between pod yield and various traits including plant height, primary branches/ plant, pods/plant, 100 pod weight, sound mature kernel, and kernel yield. This suggests that improving pod yield could be achieved through the selection of traits positively correlated with it. These results are similar with Vasanthi *et al*., (2015) for primary branches/plant and Hampannavar *et al*., (2018) for pods/plant and kernel yield. Moreover, pod yield displayed significant-positive correlations with plant height, 100 pod weight, and sound mature kernel, while exhibiting a significant-negative association with primary branches/plant. The increase in pod yield was observed to correlate with plant height, 100 pod weight, sound mature kernel, and pods/plant. This result aligned with the results of Chaudhari *et al*., (2017).

Path coefficient analysis revealed relationships among different yield attributing traits and pod yield/plant. The direct and indirect effects among various attributes are outlined in **Table 7.** The residual effect of 0.039 supports the credibility of traits in explaining variations in pod yield. Among the investigated traits, kernel yield/plant recorded strong and significantly positive direct effect on pod yield. This is followed by the sound mature kernel, number of mature pods/plants and number of secondary branches which significantly exhibited negative correlations with pod yield. These traits may be better selection criteria for higher pod yield. The significant positive correlated traits like kernel yield per plant, number of primary branches per plant had the indirect influences on the direct influenced traits like number of pods per plant, hundred pod weight for governing pod yield. The present revealed that these indirect traits effects were not much contributing to pod yield. In contrast, shelling percentage exerts a considerably weak negative direct effect on pod yield and was negatively correlated with pod yield. Similar results were also reported by Kumari and Sashidharan (2020), Trivikramareddy *et al*., (2017), Sadeghi and Niyaki (2012), and Ponnuswamy (1986). The results

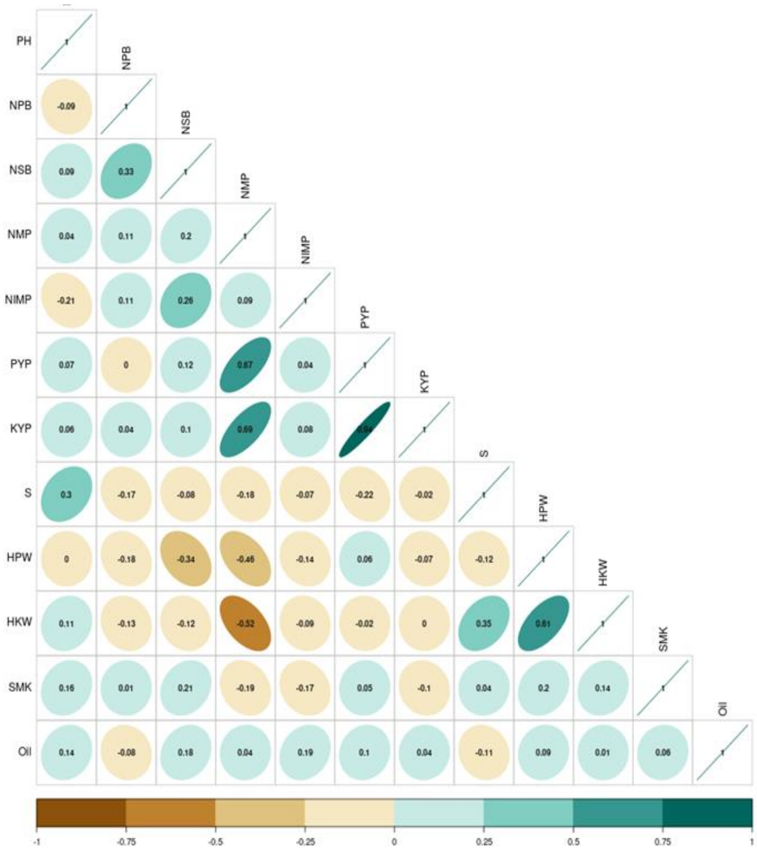

Fig 1. Correlation co-efficient between yield and yield attributing traits

Table 6. Best performing cross combination, their heterobeltiosis and standard heterosis for various traits

Characters	Best performing hybrids	Mid parent	Heterobeltiosis	Standard heterosis over check
	CO7 X ICGV15412	-9.04 *	-10.21**	-23.3**
Plant height	CO7 X ICGV15408	-8.75*	-19.41**	-22.87**
	CO7 X ICGV15427	-5.06	-33.46*	-22.31**
	VRI 9 X ICGV 15426	62.34**	42.31**	87.34**
Number of branches per plant	VRI 9 X ICGV 15432	36.26**	41.35*	86.08**
	VRI 7 X ICGV 15402	19.34**	5.75	70.89*
	K 6 X ICGV 15402	-22.99*	41.18**	22.23*
Number of pods per plant	VRI 10 X ICGV 15402	84.34*	49.51*	19.51*
	VRI 10 X ICGV 15426	-28.47*	38.36**	17.79**
Pod yield per plant	K 6 X ICGV 15402	78.24**	66.45**	55.64
	VRI 10 X ICGV 15402	60.24**	52.64**	47.51
	VRI 10 X ICGV 15426	56.78**	49.75**	40.50
Kernal yield per plant	VRI 10 X ICGV 15426	21.29*	17.14*	18.61*
	K 6 X ICGV 15402	2303*	19.46**	17.46**
	VRI 9 X ICGV 15432	-16.59*	17.56*	-25.03*
Hundred kernel yield	VRI 10 X ICGV 15402	-54.30**	-59.84**	-63.47**
	VRI 10 X ICGV 15412	-26.37**	-30.21**	-36.53**
	CO 7 x ICGV 15402	-11.63*	-18.15*	-15.02*
Hundred kernel weight	VRI 10 X ICGV 15402	2.82	13.49*	8.30**
	VRI 10 X ICGV 15426	18.13**	11.46*	9.50*

*, Significant at 5%; **, significant at 1%.

Table 7. Path effects of yield and yield attributing traits in groundnut

Traits	PH	NPB	NSB	NMP	NIMP	KYP	S	HPW	HKW	SMK	Correlations PYP
PH	**0.053**	0.006	0.001	0.004	0.001	0.050	-0.064	0.000	0.002	0.022	0.08
NPB	-0.005	**-0.060**	0.003	0.010	0.000	0.033	0.036	-0.018	-0.002	0.002	-0.01
NSB	0.005	-0.020	**0.011**	0.019	-0.001	0.092	0.018	-0.033	-0.002	0.028	0.12*
NMP	0.002	-0.006	0.002	**0.094**	0.000	0.614	0.037	-0.044	-0.009	-0.025	0.67**
NIMP	-0.011	-0.007	0.003	0.008	**-0.003**	0.070	0.016	-0.014	-0.001	-0.023	0.04
KYP	0.003	-0.002	0.001	0.065	0.000	**0.889**	0.004	-0.007	0.000	-0.014	0.94**
S	0.016	0.010	-0.001	-0.017	0.000	-0.015	**-0.213**	-0.011	0.006	0.005	-0.22*
HPW	0.000	0.011	-0.004	-0.044	0.000	-0.063	0.026	**0.096**	0.010	0.026	0.06
HKW	0.006	0.008	-0.001	-0.049	0.000	-0.001	-0.075	0.058	**0.017**	0.019	-0.02
SMK	0.009	-0.001	0.002	-0.018	0.001	-0.093	-0.009	0.019	0.002	**0.133**	0.25*

Residuals: 0.039. The last column is the correlations with the dependent variable.
* significant at 5%, ** significant at 1%.
PH-Plant height (cm), NPB -Number of primary branches per plant, NSB-Number of secondary branches per plant, NMP- Number of mature pods per plant, NIMP- Number of immature pods for plant, PYP- Pod yield per plant (g), KYP- Kernel yield per plant (g), S%- Shelling percentage, HPW-Hundred pod weight (g), HKW-Hundred kernel weight (g),

indicate that these traits could serve as valuable indicators for selecting groundnut plants with enhanced pod yield. Prioritizing these traits during the selection process holds the potential to increase the likelihood of developing groundnut genotypes with improved pod yield. By focusing on these traits, breeders can effectively guide their efforts toward enhancing groundnut productivity.

In conclusion, the parent VRI 7 was considered as good combiner for pod yield per plant and component characters and could be utilized in breeding programme. Most of the high pod yielding crosses exhibiting desirable sca effects involved parents with high and low gca effects, indicating the influence of non-additive gene interactions in these crosses. Among the hybrids VRI 7 x ICGV 15402, VRI 7 x ICGV 15427 exhibited superior *per se* performance and had one of the parents with good general combining ability. Hence, selection could be made in early generation itself, in these crosses. In addition, heterosis breeding offers promise in enhancing groundnut genotypes for pod yield per plant and related traits. Varieties like K 6 and VRI 10 have potential as better parents in hybridisation. Through strategic inter-mating and crossing among suitable F_1s, the frequency of desirable segregants can be significantly increased in subsequent generations. These segregating populations, subjected to rigorous and objective-oriented selection, hold potential for crop improvement.

REFERENCES

Arunachalam, V., Bandyopadhyay, A., Nigam, S.N. and Gibbons, R.W. 1984. Heterosis in relation-genetic divergence and specific combining ability in groundnut (*Arachis hypogaea* L.). *Euphytica*, **33**(1): 33-39. [Cross Ref]

Azad, A.K., Alam, S., Hamid, A., Rafii, Y. and Malek, M.A. 2014. Combining ability of pod yield and related traits of groundnut (*Arachis hypogaea* L.) under Salinity Stress. *The Scientific World Journal*, **7**(3): 1-7. [Cross Ref]

Banoth M, Prabhavathi, K., Bhadru, D. and Mallaiah, B. 2021(a). Screening technique for identification of resistant genotypes against post flowering stalk rot complex caused by *Macrophomina phaseolina* in maize (*Zea mays* L.). *International Journal of Current Microbiology and Applied Sciences*, **10**(01): 3535-3544. [Cross Ref]

Banoth, M., Nunavath, U.S., Bhimireddy, S., Konne, D., Lekshmi, L.A., Govada, V. and Lavudya, S. 2023(a). Conventional and molecular breeding strategies for improvement of drought tolerance cultivars in rice: Recent approaches and outlooks. *Environment Conservation Journal*, **24**(4), 367–381. [Cross Ref]

Banoth, M., Prabhavathi, K., Bhadru, D. and Mallaiah, B. 2021(b). Breeding resistance for post flowering stalk rot (*Macrophomina phaseolina*) in maize identification of resistance against post flowering stalk rot (*Macrophomina phaseolina*) in Maize. *Journal of Experimental Agriculture International*, **43**(4): 44-55. [Cross Ref]

Banoth, M., Subbarayan, S., Sadasivam, M., Marimuthu, M., Sivakami, R. and Boopathi, N.M. 2023(b). Biochemical analysis of metabolites in cotton (*Gossypium hirsutum* L.) conferring resistance-Leaf hopper *Amrasca biguttula biguttula* (Ishida). *Electronic Journal of Plant Breeding*, **14**(3): 965-75. [Cross Ref]

Chaudhari, R.M., Kachhadia, V.H., Vachhani, J.H. and Virani, M.B. 2017. Genetic variability studies in groundnut (*Arachis hypogaea* L.). *Electronic Journal of Plant Breeding*, **8**(4): 1288-1292. [Cross Ref]

Deshmukh, S.K., Zade, V.R. and Reddy, P.S. 1985. Heterobeltiosis in groundnut. *Indian Journal Agricultural Sciences*, **85**: 358-361.

Dwivedi, S.L., Nagabhushanam, G.V.S., Nigam, S.N., Raghunath, K. and Jambhunathan, R. 1994. Germplasm enhancement for seed quality traits in groundnut. *International Journal Arachis Newsletter,* **14**: 14-15.

Fonseca, S. and Patterson, F. 1968. Hybrid vigour in seven parent diallel crosses in common winter wheat (*Triticum aestivum* L.). *Journal of Crop Science*, **8**: 85-95. [Cross Ref]

Ganesan, K.N., Paneerselvam, R. and Manivannan, N. 2010. Identification of crosses and good combiners for developing new genotypes in groundnut (*Arachis hypogaea* L.). *Electronic Journal of Plant Breeding*, **1**(2): 167-172.

Golakia, P.R., Makne, V.G. and Monpara, B.A. 2005. Heritable variation and association in Virginia runner and Spanish bunch group of groundnut (*Arachis hypogaea* L.). *National Journal of Pant Improvement*, **7**: 50-53.

Gor, H.K., Dhaduk, L.K. and Lata, R. 2012. Heterosis and inbreeding depression for pod yield and its components in groundnut (*Arachis hypogaea* L.). *Electronic Journal of Plant Breeding*, **3**(3): 868-874.

Hampannavar, M.R., Khan, H., Temburne, B.V., Janila, P. and Amaregouda, A. 2018. Genetic variability, correlation and path analysis studies for yield and yield attributes in groundnut (*Arachis hypogaea* L.). *Journal Pharmacology Phytochemistry*, **7**(1): 870-874.

Hariprasanna, K., Chuni, L., Radhakrishnan, T., Gor, H.K. and Chikani, B.M. 2008. Analysis of diallel cross for some physical-quality traits in peanut (*Arachis hypogaea* L.). *Euphytica*, **160**(1): 49-57. [Cross Ref]

Harisudan, C. and Subrahmaniyan, K. 2020. Evaluation of irrigation levels and plant geometry for drip irrigation in groundnut (*Arachis hypogaea* L.). *Journal Oilseeds Res*., **37**(4): 261-271. [Cross Ref]

Jayalakshmi, V., Raja Reddy, C., Reddy, P.V. and Lakshmikantha Reddy, G. 2002. Combining ability analysis of morphological and physiological attributes in groundnut (*Arachis hypogaea* L.). *Indian Journal of Agricultural Research*, **36**(3): 177-181.

Jivani, L.L., Khanpara, M.D., Kachhadia, V.H. and Modhvadia, J.M. 2008. Heterosis and inbreeding depression for pod yield and its related traits in Spanish bunch groundnut (*Arachis hypogaea* L.). *Research on Crops*, **9**: 670-674.

John, K. and Reddy, R.P. 2014. Combining ability and heterosis for yield and water use efficiency traits in groundnut. *Legume Research-An International Journal*, **373**: 235-244. [Cross Ref]

John, K., Reddy, R.P., Reddy, H.K., Sudhakar, P. and Reddy, N.P. 2012. Heterosis and inbreeding depression for vegetative traits in groundnut (*Arachis hypogaea* L.). *Legume Research-An International Journal*, **35**(1): 36.

Kempthorne, O. 1957. An Introduction to Genetic Statistics. John Wiley and Sons Inc., New York, pp. 545.

Khote, A.C., Patil, P.P., Patil, S.P. and Walke, B.K. 2009. Genetic variability studies in groundnut (*Arachis hypogaea* L.). *International Journal of Plant Science*, **4**: 141-149.

Kumari, K. and Sashidharan, N. 2020. Studies on genetic variability, correlation and path coefficient analysis for morphological and yield traits in different *Arachis* spp. *International Journal of Current Microbiology and Applied Sciences*, **9**(11): 1030-1039. [Cross Ref]

Madhu, B., Sivakumar, S., Manickam, S., Murugan, M., Rajeswari, S. and Boopathi, N. M. 2024. Evaluating morphological and biochemical traits in cotton genotypes mediating resistance to leafhopper *Amrasca biguttula biguttula* (Ishida). *Pakistan Journal of Agricultural Sciences*, **61**(1): 103-115. https://doi.org/10.21162/PAKJAS/24.69

Madhu, B., Sukrutha, B., Singh, N.U. and Venkateswarao, G. 2023a. Breeding strategies for improvement of drought tolerance in rice: Recent Approaches, and Future Outlooks. Sustainable Rice Production-Challenges, Strategies and Opportunities. IntechOpen. [Cross Ref]

Madhu. B., Sivakumar, S., Manickam, S., Murugan, M., Rajeswari, S. and Boopathi, N.M. 2023(b). Improvising cotton (*Gossypium hirsutum* L.) genotypes for compact plant architecture traits suitable for mechanical harvesting. *Indian Journal of Genetics and Plant Breeding*, **83**(03): 398-406. [Cross Ref]

Manivannan, N. 2014. TNAUSTAT-Statistical package. Retrived from https://sites.google.com/site/tnaustat

Manivannan, N., Muralidharan, V. and Mothilal, A. 2008. Combining ability analysis in groundnut (*Arachis hypogaea* L.). *Madras Agricultural Journal.*, **95**(1-6): 14-17.

Meredith, W.R. and Bridge, R.R. 1972. Heterosis and gene action in cotton (*Gossypium hirsutum*). *Journal Crop Science*, **12**: 304-310. [Cross Ref]

Mothilal, A. and Ezhil, A. 2010. Combining ability analysis for yield and its components in groundnut (*Arachis hypogaea* L.). *Electronic Journal of Plant Breeding*, **1**(2): 162-166.

Onyia, V.N. 2011. Combining ability analysis for yield and yield components in eight breeding lines of rice (*Oryza sativa* L.). *Agro-Science*, **10**(2): 7-15. [Cross Ref]

Ponnuswamy, A.S. 1986. Influence of seed size on pod and haulm production and yield in groundnut (*Arachis hypogaea* L.) cv. POL 1 and TMV 2. *Madras Agricultural Journal,* **73**(6): 313-316. [Cross Ref]

Rashid, M., Cheema, A.A. and Ashraf, M. 2007. Line × Tester analysis in basmati rice. *Pakistan Journal of Botany*, **39**(6): 2035-2042.

Rekha, D., Savithramma, D.L., Shankar, A.G. and Marappa, N. 2009. Combining ability studies for growth and yield traits in groundnut (*Arachis hypogaea* L.). *Environment and Ecology,* **27**(1): 117-120.

Sadeghi, S.M. and Niyaki, S.A.N. 2012. Correlation and path coefficient analysis in peanut (*Arachis hypogaea* L.) genotypes under drought stress and irrigated conditions. *Annals of Biological Research*, **3**(6): 2593-2596.

Sangeetha, V.R., Viswanathan, P.L. Manonmani, S. Rajendran, L. and Selvakumar, T. 2021. Estimation of heterosis and combining ability of yield traits in groundnut (*Arachis hypogaea* L.). *Indian Journal of Agricultural Research*, **55**: 310-316.

Savithramma, D.L, Rekha, D. and Sowmya, H.C. 2010. Combining ability studies for growth and yield traits in groundnut (*Arachis hypogaea* L.). *Electronic Journal of Plant Breeding*, **1**(4): 1010-1015.

Sharma, L.K. and Gupta, S.C. 2010. Heterosis for pod yield and related attributes in groundnut (*Arachis hypogaea* L.). *Research on Crops*, **11**: 465-470.

Shendekar, S.A., Gulwane, V.P., Yadav, T.V., Madhu, B., Meshram, M.R., Gadpayale, D.P. and Kumar, M.N. 2023. Genetic variability, mean performance studies in groundnut (*Arachis hypogaea* L.) under controlled environmental condition. *The Pharma Innovation Journal*, **12**(5): 3221-3224.

Shoba, D.N., Manivannan, N. and Vindhiyavarman, P. 2010. Gene effects of pod yield and its components in three crosses of groundnut (*Arachis hypogaea* L.). *Electronic Journal of Plant Breeding*, **1**(6): 1415-1419.

Shull, G.H. 1948. What is heterosis? *Genetics*, **33**: 439-446. [Cross Ref]

Sprague, G. R. and Tatum, A. 1942. General vs specific combining ability in single crosses of cotton. *Journal of the American Society of Agronomy*, **34**: 923-932. [Cross Ref]

Trivikramareddy, A., Reddi, M.S., Vijayabharathi, A.T., Lakshmi, P., Lakshmikantha, G.R and Jayalakshmi, V. 2017. Correlation and path analysis of kernel yield and its components in groundnut (*Arachis hypogaea* L.). *International Journal of Current Microbiology and Applied Sciences*, **6** (12): 10-16. [Cross Ref]

Vasanthi, R.P., Suneetha, N. and Sudhakar, P. 2015. Genetic variability and correlation studies for morphological, yield and yield attributes in groundnut (*Arachis hypogaea* L.). *Legume Research*, **38**(1): 9-15. [Cross Ref]

Vishnuvardhan, K.M., Vasanthi, R.P. and Reddy, K.H. 2011. Combining ability of yield, yield traits and resistance to late leaf spot and rust in groundnut. *Journal of SAT Agricultural Research*, **9:** 1-6.

Waghmode, B.D., Kore, A.B., Navhale, V.C., Sonone, N.G. and Thaware, B.L. 2017. Genetic analysis of promising crosses and good combiners for developing new genotypes in groundnut (*Arachis hypogaea* L.). *International Journal of Current Microbiology Applied Science,* **6**(7): 324-331. [Cross Ref]

Yadav, K.N.S., Gowda, M.B., Savithramma, D.L. and Girish, G. 2006. Studies on combining ability for pod yield and itstble components in groundnut. *Crop Research,* **32**(1): 90-93.