Available online at www.ijpab.com

DOI: http://dx.doi.org/10.18782/2582-2845.8450

ISSN: 2582 – 2845

Ind. J. Pure App. Biosci. (2020) *8*(6), 190-199

Indian Journal of Pure & Applied Biosciences

Peer-Reviewed, Refereed, Open Access Journal

Research Article

Character Association and Path Coefficient Analysis Studies for Quantitative Traits in F_3 Generation of Groundnut (*Arachis hypogaea* L.)

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Received: 2.11.2020 | Revised: 29.11.2020 | Accepted: 5.12.2020

ABSTRACT

In groundnut, correlation and path coefficient analysis was carried out to identify the suitable selection indices in F_3 generation of nine crosses viz., TLG 45 x ICGV-05155, JL – 501 x KDG-128, K-1641 x ALR-3, SG-99 x R-8808, ALG-234 x ICGV-00350, AG-24 x ICGV-6110, JSSP-LS-58 x CS-19, TPG-41 x GG-16 and J-89 x ISK-I-16-13. Correlation analysis revealed that the traits viz., pod yield per plant had positive and highly significant correlation with plant height, number of matured pods per plant, number of immature pods per plant, kernel yield per plant and harvest index. These characters can be considered as a selection criteria for higher yield as they were mutually and directly associated with pod yield per plant. Out of thirteen characters studied, kernel yield per plant and harvest index (%) exerted maximum positive direct effect on pod yield per plant. Indirect effect of harvest index through kernel yield per plant were high. Therefore, number of matured pods per plant, kernel yield per plant and harvest index should be considered as selection criteria for improving pod yield per plant in groundnut.

Keywords: *Groundnut, Correlation, Path coefficient analysis and Yield.*

INTRODUCTION

Groundnut is an allotetraploid (2n=4x= 40) with a basic chromosome number of x=10 and it is highly self-pollinated crop having cleistogamous flowers. Groundnut is an unpredictable crop due to its underground pods development. It is an annual legume with high quality edible oil and easily digestible protein of its kernels. Pod yield is not only polygenically controlled, but also influenced by its component characters. Direct selection of pod yield would not be reliable approach without giving due importance to its genetic nature, owing to its complex nature of inheritance. Information on phenotypic and genotypic interrelationship of pod yield with its components characters and also among the characters themselves would be very much useful to the plant breeder in developing an appropriate breeding strategy.

Cite this article: Godhani, P. P., Jivani, L. L., Patel, B. M., & Raval, L. J. (2020). Character Association and Path Coefficient Analysis Studies for Quantitative Traits in F_3 Generation of Groundnut (*Arachis hypogaea* L.), *Ind. J. Pure App. Biosci. 8*(6), 190-199. doi: http://dx.doi.org/10.18782/2582-2845.8450

But, the correlations give information about the component traits they do not provide a true picture of relative importance of direct and indirect effects of these component traits on pod yield. Hence, the path coefficient analysis permits the separation of direct effects from indirect effects and gives more realistic relationship of the characters and help in effective selection. Therefore, the present study on Spanish bunch genotypes was conducted to study the correlation and path coefficients.

MATERIALS AND METHODS

The present investigation was carried out to assess the correlation and path coefficient analysis in F_3 generations of groundnut (*Arachis hypogaea* L.). The required quantity of seeds of F_3 populations and parents of nine crosses were obtained from the Main Oilseeds Research Station, Junagadh Agricultural University, Junagadh (Gujarat) and was sown in the summer- 2019 at the Main Oilseeds Research Station, Junagadh Agricultural University, Junagadh (Gujarat).

The experimental material consisted of F_3 generations of nine crosses derived from crossing among 18 parents. The crosses of the study were; TLG 45 x ICGV-05155, JL – 501 x KDG-128, K-1641 x ALR-3, SG-99 x R-8808, ALG-234 x ICGV-00350, AG-24 x ICGV-6110, JSSP-LS-58 x CS-19, TPG-41 x GG-16 and J-89 x ISK-I-16-13. Nine F_3 populations and 18 parental lines have been sown during summer season on 6^{th} February, 2019 in a Randomized Complete Block Design with 2 replications. The observations were taken from randomly selected 5 plants from parents and 10 plants from each of fifteen sown rows of every crosses were recorded for the characters, *viz*., days to appearance of first flower, days to maturity, number of primary branches per plant, plant height, number of matured pods per plant, number of immature pods per plant, pod yield per plant, shelling outturn, kernel yield per plant and harvest index. Except, days to appearance of first flower and days to maturity where, data recorded on plot basis. Average value was used for the statistical analysis. The data was analysed to work out correlation and path coefficient analysis.

In the present study, simple correlation coefficient between the characters was worked out according to the procedure of Al-Jibouri et al. (1958). The path coefficient analysis was adopted to partition the correlation coefficient into direct and indirect effects and it was done as per the method suggested by Dewey and Lu (1959) and ranked on the scales given by Lenka and Mishra (1973).

RESULTS AND DISCUSSION

The aim of correlation studies is a primarily to know the suitability of various characters for indirect selection (Prabhu et al., 2016). Correlation studies provide information on the nature and extent of association between any two metric traits and it will be possible to bring about genetic upgradation in one trait by selection of the other of a pair. Path analysis splits the correlation coefficient into direct and indirect effects. Path analysis showing direct and indirect effects are effective to get high selection response simultaneously for several characters from the diverse populations.

Correlation coefficient

Correlation may result from pleiotropy, linkage or physiological association among characters. The linkage is a cause of transit correlations particularly in a population derived from crosses between divergent strains. The correlation is the overall or net effect of the segregating genes. Some of the genes may increase both characters causing the positive correlation, while others may increase one and decrease the other causing the negative correlation. Thus, to accumulate optimum combination of yield contributing characters in a single genotype, it is essential to know the implication of the interrelationship of various characters.

The association of yield with different yield components in nine F_3 population *viz* TLG 45 x ICGV-05155, JL – 501 x KDG-128, K-1641 x ALR-3, SG-99 x R-8808, ALG-234 x ICGV-00350, AG-24 x ICGV-6110, JSSP-LS-58 x CS-19, TPG-41 x GG-16 and J-89 x ISK-I-16-13, were estimated and presented in Table 1.

Days to appearance of first flower with others

At both genotypic and phenotypic levels, days to appearance of first flower was positively and significantly associated with number of primary branches per plant, plant height, number of matured pods per plant, number of immature pods per plant, kernel yield and harvest index (%). With number of matured pods per plant in Cross 3 (r_g = 0.4245**, r_p = 0.4121**), Cross 6 (r_g = 0.4234**, r_p = 0.4009**) and in Cross 8 (r_g = 0.4481**, r_p = 0.3453**); kernel yield per plant in Cross 3 (r_g = 0.3776**, r_p = 0.3234**) and Cross 4 (r_g = 0.7664**, r_p = 0.6763**). Parameshwarappa et al. (2008) found similar results for this character. While negative and significant association with days to maturity, number of primary branches per plant, plant height, kernel yield and harvest index (%). With days to maturity in Cross 1 (r_g = -0.3571**, r_p = -0.3087**), Cross 2 (r_g = -0.3699**, r_p = -0.3616**) and Cross 9 (r_g = -0.3367**, r_p = -0.1646*). This suggested that early flowering would tend to early maturity. Therefore, days to first flowering should be considered important component for identifying early flowering genotypes in groundnut.

Thus, association of days to appearance of first flower with these traits varied from cross to cross. Such variation in strength and direction of associations could be attributed to the reflection of gene combinations specific for theses genotypes and not genetic linkage or pleiotropy.

Days to maturity with others

At both genotypic and phenotypic levels, days to maturity was positively and significantly associated with number of primary branches per plant, plant height, number of matured pods per plant, number of immature pods per plant, kernel yield, harvest index (%) and pod yield per plant. With number of matured pods per plant in Cross 5 (r_g = 0.2934**, r_p = 0.2598**), Cross 7 (r_g = 0.2818**, r_p = 0.2776**), Cross 8 (r_g = 0.6247**, r_p = 0.5052**) and Cross 9 (r_g = 0.8715**, r_p = 0.4169**); kernel yield per plant in Cross 8 (r_g = 0.2759**, r_p = 0.2200**); harvest index in the Cross 8 (r_g = 0.5430**, r_p = 0.3943**); pod yield per plant in Cross 4 (r_g = 0.2945**, r_p = 0.2849**) and Cross 8 (r_g = 0.3566**, r_p = 0.3546**); Zaman et al. (2011) and Bhargavi et al. (2015) reported same results for this character. While negative and significant association with days to appearance of first flower, primary branches per plant, plant height, kernel yield, harvest index (%) and pod yield per plant. With kernel yield per plant in Cross 5 (r_g = -0.3622**, r_p = -0.2780**), Cross 6 (r_g = -0.3121**, r_p = -0.2481**) and Cross 7 (r_g = -0.9961**, r_p = -0.3228**); pod yield per plant in Cross 2 (r_g = -0.1659*, r_p = -0.1691*), Cross 6 (r_g = -0.3714**, r_p = -0.3694**) and Cross 9 (r_g = -0.7682**, r_p = -0.4035**); Jogloy et al. (2011) reported same results for this character.

Pod yield and days to maturity exhibited significant association between them in most of the crosses studied, which was positively associated at genotypic level in Cross 4 and Cross 8; hence it may be possible to select lines with higher yield without changing in maturity time. Reddy et al. (1986) and Tekale et al. (1988) showed positive and significant correlation between pod yield per plant and days to maturity.

Number of primary branches per plant with others

At both genotypic and phenotypic levels, number of primary branches per plant was positively and significantly associated with days to appearance of first flower, days to maturity, plant height, number of matured pods per plant, number of immature pods per plant, kernel yield, harvest index (%) and pod yield per plant. With days to maturity in Cross 5 (r_g = 0.5626**, r_p = 0.5340**), Cross 6 (r_g = 0.1978*, r_p = 0. 1917*), Cross 8 (r_g = 0.5195**, r_p = 0. 4929**), and Cross 9 (r_g = 0.5753**, r_p = 0. 3410**); number of mature pods per plant in Cross 6 (r_g = 0.3217**, r_p = 0.3092**) and Cross 8 (r_g = 0.5855**, r_p = 0.4301**); kernel yield per plant in Cross 7 (r_g = 1.0776**, r_p = 0.1952*) and Cross 9 (r_g = 0.2977**, r_p = 0.2283**);harvest index in Cross 5 (r_g = 0.4884**, r_p = 0.4084**), Cross 7 (r_g = 0.3057**, r_p = 0. 2759**). Kumar et al. (2010), Shreya et al. (2015) and Vasanthi et al. (2015) reported same results for this character. While, negative and significant association with days to appearance of first flower, days to maturity, plant height, number of matured pods per plant, number of immature pods per plant, kernel yield, harvest index (%) and pod yield per plant.

Plant height with other

Associations between plant height with other characters were found significantly positive at both genotypic and phenotypic levels with days to appearance of first flower, days to maturity, primary branches per plant, number of matured pods per plant, number of immature pods per plant, kernel yield, harvest index (%) and pod yield per plant. So, in Cross 2 (r_g = 0.1750*, r_p = 0.1719*) and Cross 5 (r_g = 0.3149**, r_p = 0.3062**) in days to maturity Cross 2 (r_g = 0.3333**, r_p = 0.3273**) and Cross 5 (r_g = 0.5404**, r_p = 0.5210**) in number of matured pods per plant, Cross 3 (r_g = 0.3948**, r_p = 0.3456**) and Cross 8 (r_g = 0.3168**, r_p = 0. 2821**) in kernel yield per plant. Similar observations were also reported by Tekale et al. (1988). At genotypic and phenotypic levels both negative and significant associations with days to maturity, primary branches per plant, number of matured pods per plant, number of immature pods per plant, and kernel yield.

Number of matured pods per plant with other

At both genotypic and phenotypic levels, number of matured pods per plant was positively and significantly associated with days to appearance of first flower, days to maturity, number of primary branches per plant, number of immature pods per plant, kernel yield, harvest index (%) and pod yield per plant. So in days to maturity in Cross 1 (r_g = 0.2999**, r_p = 0.2757**), Cross 7 (r_g = 2818**, r_p = 0.2776**) and Cross 8 (r_g = 0.6247**, r_p = 0.5052**); kernel yield per plant in Cross 1 (r_g = 0.4814**, r_p = 0.3453**) and Cross 8 (r_g = 0.2418**, r_p = 0.2506**); pod yield per plant in Cross 1 (r_g = 0.2520**, r_p = 0.2476**), Cross 2 (r_g = 0.3219**, r_p = 0.3223**), Cross 3 (r_g = 0.2216**, r_p = 0.2139**), Cross 4 (r_g = 0.2265**, r_p = 0.2084**) and Cross 8 (r_g = 0.3582**, r_p = 0.2651**); Nirmala and Jayalakshmi (2015) reported same results for this characters. while negative and significant association with number of primary branches per plant, plant height, kernel yield, harvest index (%) and pod yield per plant.

Number of immature pods per plant with other

Number of immature pods per plant had positive and significant associations at both genotypic and phenotypic levels with days to appearance of first flower, days to maturity, number of primary branches per plant, number of matured pods per plant, kernel yield and pod yield per plant. So, with days to maturity in Cross 1 (r_g = 3367**, r_p = 0.2732), Cross 3 (r_g = 0.2108**, r_p = 0.2162**), Cross 5 (r_g = 0.1694*, r_p = 0.1784*) and Cross 8 (r_g = 0.4250**, r_p = 0.3867**); kernel yield per plant in Cross 1 (r_g = 0.1832*, r_p = 0.2008*) and pod yield per plant in Cross 2 (r_g = 0.2117**, r_p = 0.1849*); Nirmala and Jayalakshmi (2015) reported same results for this character. Number of immature pods per plant had negative and significant association at both genotypic and phenotypic levels with number of primary branches per plant, plant height and kernel yield per plant. As number of immature pods per plant is undesirable character for prime pod yield so, we consider negative and significant correlation beneficial and we can improve yield contributing character by using such crosses.

Kernel yield per plant (g) with other

Correlation of kernel yield per plant was significantly positive at both genotypic and phenotypic levels with days to appearance of first flower, days to maturity, number of primary branches per plant, plant height, number of matured pods per plant, number of immature pods per plant, pod yield per plant, kernel yield per plant and harvest index. Similar observations reported by Kumar et al. (2014) and Choudhary et al. (2016). Negative and significant association with days to appearance of first flower in Cross 9 (r_g = -0.3190**, r_p = -0.2491**); number of matured pods per plant in Cross 5 (r_g = -0.4939**, r_p = -0.4733**).

Harvest index (%) with other

Correlation of harvest index (%) was significantly positive at both genotypic and phenotypic levels with days to appearance of first flower, days to maturity, number of primary branches per plant, plant height, number of matured pods per plant and only at genotypic level with kernel yield per plant. While negative and significant only at genotypic level with plant height in Cross 8 (r_g = -0.2199**); number of matured pods per plant in Cross 8 (r_g = -0.2354**). Such relationships between these characters were earlier reported by Bhargavi et al. (2015).

PATH COEFFICIENT ANALYSIS

In fact, pod yield per plant is a polygenic trait, influenced by its several components as well as indirectly *via* other traits, which create complex situation before a breeder for making selection. In such situation, path coefficient analysis could provide a more realistic picture of the interrelationship as it consider direct as well as indirect effects of the variables by partitioning the correlation coefficient. In the present study, path coefficient was worked out for all significant characters out of thirteen characters in all significant groundnut crosses and the results have been presented and discussed in the following pages:

Days to appearance of first flower and others

The partitioning of correlation coefficient into direct and indirect effects of days to appearance of first flower with other traits (Table 2) indicated that direct effect of this trait was negligible to high in both directions towards pod yield per plant in all the crosses. Our results are in accordance with the results reported by Mane et al. (2008). Its indirect effect was moderate towards pod yield per plant through kernel yield per plant in Cross 4 (-0.2936) and Cross 3 (0.2861). Earlier such type of relationship was reported by Giri et al. (2009). Its indirect effect through other characters towards pod yield per plant was negligible and low in most of the crosses. Although, the correlations of days to appearance of first flower with pod yield per plant was positive and significant in the Cross 2 (0.1992) and Cross 4 (0.6023).

Days to maturity and others

Direct and indirect effects of days to maturity with other traits (Table 2) indicated that direct effect of this trait was negligible to moderate in both directions towards pod yield per plant in all the crosses. Babariya and Dobariya (2012) reported similar result. Its indirect effect was high towards pod yield per plant through harvest index (%) in Cross 6 (-0.4456) and in Cross 8 (0.3958) and moderate in Cross 9 (-0.2439), Azad and Hamid (2000) reported similar result. Its indirect effect through other character towards pod yield per plant was negligible in all the crosses. The correlation of number of primary branches per plant with pod yield per plant was positive and significant Cross 4 (0.2849), Cross 6 (-0.3694), Cross 8 (0.3546) and Cross 9 (-0.4035).

Number of primary branches per plant and others

The examination of direct and indirect effects of primary branches per plant (Table 2) revealed that the contribution of direct effect with other traits were negligible to moderate in both direction. Raju et al. (1981) reported that number of primary branches per plant had negligible direct effect on pod yield per plant. Its indirect effect was high towards pod yield per plant through harvest index (%) in Cross 2 (0.3859) and Cross 5 (0.3132) and moderate in Cross 7 (0.2020) and low in Cross 8 (0.1769). Its indirect effect through other character towards pod yield per plant was negligible in rest of all the crosses. The correlation of number of primary branches per plant with pod yield per plant was found positive significant in Cross 5 (0.3848), Cross 7 (0.4031) and Cross 8 (0.3405).

Plant height (cm) and others

The examination of direct and indirect effects of plant height (Table 2) revealed that the contribution of direct effect with other traits were positive and negligible in both direction except for Cross 4 (-0.1470). Its indirect effect was high towards pod yield per plant through kernel yield per plant in Cross 3 (0.3057). Singh and Singh (2001) reported that most of the characters contributed indirectly to pod yield per plant *via* kernel yield. Its indirect effect through other characters towards pod yield per plant was negligible to low in all the crosses. The correlation of plant height with pod yield per plant was positive and significant in Cross 3 (0.4377), Cross 4 (0.2060) and Cross 7 (0.3719).

Number of matured pods per plant and others

The partitioning of correlation coefficient into direct and indirect effects of number of matured pods par plant with other traits (Table 2) indicated that direct effect of this trait was negligible to high in both directions towards pod yield per plant in all the crosses. Its indirect effect was moderate towards pod yield per plant through kernel yield per plant in Cross 2 (-0.2928). Earlier such type of relationship was reported by Prabhu et al. (2017). Its indirect effect through other characters towards pod yield per plant was negligible in most of the crosses. Similar results were earlier obtained by Abraham (1990). Although, the correlations of number of matured pods per plant with pod yield per plant was positive and significant in Cross 1 (0.2476), Cross 2 (0.3223), Cross 3 (0.2139), Cross 4 (0.2084) and Cross 8 (0.2651).

Number of immature pods per plant and others

The examination of direct and indirect effects of number of immature pods per plant (Table 2) revealed that the contribution of direct effect with other traits were negative and negligible to low towards pod yield per plant. Its indirect effect through other characters towards pod yield per plant was negligible in most of the crosses except Cross 2 (0.1545) and Cross 3 (0.2024) *via* matured pods per plant and Cross 2 (-0.2046) and Cross 3 (-0.1346) *via* kernel yield per plant. Earlier such results reported by Raju et al. (1981). The correlation of number of immature pods per plant with pod yield per plant was positive significant in Cross 2 (0.1849).

Kernel yield per plant (g) and others

Path coefficient values presented in Table 2 for kernel yield per plant indicated that this character was identified as an important component of pod yield per plant since it exhibited strong and positive association with pod yield per plant and also expressed low to high and positive direct effect in most the crosses. Such direct effect towards pod yield per plant was reported earlier by Azad and Hamid (2000) and Kumar et al. (2012). Hence, it would be rewarding to give due importance on the selection of this character for rapid improvement in pod yield of groundnut.

Its indirect effect was negligible to in all the crosses for all the characters except for days to appearance of first flower in Cross 4 (0.4044) and harvest index (%) in all the crosses. It's high and positive direct effects indicated that this character should be considered as important component of pod yield per plant and maximum weightage should be given to this trait during selection programme. Earlier Sawarganokar et al. (2010) also reported high direct effect of kernel yield per plant towards pod yield per plant. The correlation of kernel yield per plant with pod yield per plant was positive and significant in Cross 1 (0.7905), Cross 3 (0.8655), Cross 4 (0.2895), Cross 7 (0.2206), Cross 8 (0.6414) and Cross 9 (0.4251).

Harvest index (%) and others

Path coefficient values presented in for harvest index (%) (Table 2) indicated that this character was identified as an important component of pod yield per plant since it exhibited strong and positive association with pod yield per plant and also expressed high to very high and positive direct effect in all the crosses. Such direct effect towards pod yield per plant was reported earlier by Vaddoria and Patel (1992), Bera and Das (2000) and Choudhary et al. (2016). Its indirect effect was higher towards pod yield per plant through days to appearance of first flower in Cross 4 (0.2127) and kernel yield per plant in all the crosses except Cross 1 (-0.1581) and Cross 4 (-0.1918). Earlier such type of relationship was reported by Abraham et al. (1990).

Its indirect effect was negligible in all the crosses for all the characters. It's high and positive direct effects indicated that this character should be considered as important component of pod yield per plant and maximum weightage should be given to this trait during selection programme. Kumar et al. (2012) also reported high direct effect of harvest index (%) towards pod yield per plant. The correlation of harvest index (%) with pod yield per plant was positive and significant in all the crosses.

Table 1: Simple correlation among yield and yield attributes in F_3 population of groundnut

Character	Cross	Days to appearance of first flower	Days to maturity	Number of primary branches/plant	Plant height (cm)	Number of matured pods/plant	Number of immature pods/plants	Kernel yield/ plant (g)	Harvest index (%)
Days to maturity	1	-0.3571**							
	2	-0.3699**							
	3	-0.0068							
	4	0.1256							
	5	--							
	6	-0.1569							
	7	--							
	8	-0.0909							
	9	-0.3367**							
Number of primary branches/plant	1	0.2464**	--						
	2	0.0192	-0.2060*						
	3	0.1987*	-0.0670						
	4	0.0918	0.3788**						
	5	--	0.5626**						
	6	-0.2020*	0.1978*						
	7	--	-0.1727*						
	8	0.1234	0.5195**						
	9	0.2533**	0.5753**						
Plant height (cm)	1	-0.5641**	--	--					
	2	0.2211**	0.1750*	-0.2650**					
	3	-0.0573	-0.2592**	--					
	4	-0.0702	0.1553	--					
	5	--	0.3149**	0.0317					
	6	-0.2325**	-0.3715**	0.3132**					
	7	--	-0.0724	0.6460**					
	8	0.1113	-0.3290**	-0.2564**					
	9	0.3220**	-0.0757	0.0006					
Number of matured pods/plant	1	0.1256	--	--	--				
	2	0.0327	0.0141	-0.5810**	0.3333**				
	3	0.4245**	-0.0272	--	-0.2215**				
	4	0.0684	0.0928	--	-0.0743				
	5	--	0.2934**	0.1243	0.5404**				
	6	0.4234**	0.0144	0.3217**	--				
	7	--	0.2818**	-0.047	-0.2047*				
	8	0.4481**	0.6247**	0.5855**	-0.1515				
	9	-0.0729	0.8715**	0.0596	--				
Number of immature pods/plants	1	0.3062**	--	--	--	0.6282**			
	2	0.1252	-0.1204	-0.3938**	0.2131**	0.5267**			
	3	0.0211	0.2108**	--	-0.0890	0.5024**			
	4	0.0025	-0.0097	--	-0.1960*	0.5362**			
	5	--	0.1694*	0.0647	0.6661**	--			
	6	0.1291	0.0044	-0.3600**	--	-0.1847*			
	7	--	0.0688	0.3465**	0.0043	0.1275			
	8	0.1493	0.425**	0.1826**	-0.3048**	0.2629**			
	9	0.3306**	0.2971**	0.0433	--	--			
Kernel yield/plant (g)	1	-0.0125	--	--	--	0.4814**	0.1832*		
	2	0.1400	0.101	-0.2152**	-0.6217**	-0.8086**	-0.5252**		
	3	0.3776**	-0.1188	--	0.3948**	-0.0865	-0.2272**		
	4	0.7664**	-0.124	--	0.4585**	-0.1017	0.2027*		
	5	--	-0.3622**	0.2716**	-0.2758**	--	-0.3575**		
	6	-0.0414	-0.3121**	-0.1954*	--	-0.3655**	-0.1019		
	7	--	-0.9961**	1.0776**	-0.1974*	0.1166	--		
	8	-0.1673*	0.2759**	-0.2708**	0.3168**	0.2418**	-0.4084**		
	9	-0.3190**	0.1591	0.2977**	--	--	--		
Harvest index (%)	1	0.1076	--	--	--	0.2910**	-0.0728	1.0038**	
	2	0.2711**	-0.3094**	-0.6727**	0.0447	0.4095**	0.1375	--	
	3	0.4783**	-0.1551	--	0.4618**	0.3919**	0.1086	0.8824**	
	4	0.6811**	0.0377	--	2.6547**	0.2562**	-0.0407	0.9654**	
	5	--	0.1074	0.4884**	0.0004	--	-0.1089	-0.1148	
	6	-0.3717**	-0.4535**	-0.0247	--	-0.2711**	-0.1596	--	
	7	--	-0.0823	0.3057**	0.4417**	-0.0645	--	0.9756**	
	8	-0.2067*	0.5430**	0.1831*	-0.2199**	-0.2354**	0.0569	1.0187**	
	9	0.2890**	-0.8589**	-0.1040	--	--	--	0.3673**	
Pod yield per plant (g)	1	-0.0863	--	--	--	0.2520**	-0.1088	0.9875**	0.9784**
	2	0.2157**	-0.1659**	-0.6727**	-0.0132	0.3219**	0.2117**	--	--
	3	0.1486	-0.0506	--	0.4485**	0.2216**	-0.009	1.0044**	--
	4	0.6291**	0.2945**	--	0.8920**	0.2265**	-0.0006	0.3166**	1.2749**
	5	--	0.0439	0.4291**	0.0634	--	-0.0014	-0.0184	1.1382**
	6	-0.3656**	-0.3714**	-0.0497	--	-0.4327**	-0.0968	--	--
	7	--	-0.0447	0.4516**	0.3841**	0.0085	--	0.6103**	--
	8	-0.0185	0.3566**	0.3545**	-0.0583	0.3582**	-0.145	0.8136**	1.229**
	9	0.1485	-0.7682**	0.0629	--	--	--	0.5224**	0.9361**

(--) column shows non-significant cross for that of particular character.

Table 2: Direct and indirect effect of yield components on kernel yield on F_3 population of groundnut

Character	Cross	Days to appearance of first flower	Days to maturity	Number of primary branches /plant	Plant height (cm)	Number of matured pods /plant	Number of immature pods/plants	Kernel yield/ plant (g)	Harvest index (%)	Correlated with pod yield
Days to appearance of first flower	1	-0.3184	--	--	--	-0.0395	-0.0647	0.0004	-0.0340	-0.0856
	2	-0.0325	0.0117	-0.0006	-0.0071	-0.0010	-0.004	--	--	0.1992*
	3	-0.3688	0.0015	--	0.0203	-0.1520	-0.0076	-0.1192	--	0.1466
	4	0.5979	0.0748	--	-0.0205	0.0434	0.0003	0.4044	0.2127	0.6023**
	5	--	0.0117	-0.0214	0.0623	--	0.0638	0.0358	0.0190	--
	6	0.1578	-0.0246	-0.0302	--	0.0632	0.0209	--	--	-0.3587**
	7	--	-0.099	0.0045	0.0164	-0.0428	--	0.1500	--	--
	8	0.0397	-0.0036	0.0053	0.0046	0.0137	0.0061	-0.0043	-0.0066	-0.0162
	9	-0.0677	0.0111	-0.0154	--	--	--	0.0169	-0.0191	0.1500
Days to maturity	1	0.0694	--	--	--	-0.0620	-0.0614	0.1065	0.1165	--
	2	-0.0045	0.0123	-0.0023	0.0021	0.0002	-0.0012	--	--	-0.1691*
	3	-0.0004	0.1056	--	-0.0250	-0.0018	0.0228	-0.0096	--	-0.0531
	4	0.0141	0.1128	--	0.0046	0.0103	-0.0011	-0.0118	0.0023	0.2849**
	5	--	-0.2208	-0.1179	-0.0676	--	-0.0394	0.0614	-0.0319	0.0371
	6	-0.0384	0.2460	0.0472	--	0.0034	0.0011	--	--	-0.3694**
	7	--	0.0346	-0.0047	-0.0020	0.0096	--	-0.0112	--	-0.0424
	8	0.0108	-0.1201	-0.0592	0.0391	-0.0607	-0.0465	-0.0264	-0.0474	0.3546**
	9	0.0349	-0.2122	-0.0724	--	--	--	-0.0456	0.0601	-0.4035**
Number of primary branches/plant	1	0.0331	--	--	--	-0.0343	-0.0403	0.0527	0.0456	--
	2	0.0008	-0.0079	0.0425	-0.0103	-0.0235	-0.0159	--	--	-0.6479**
	3	0.0336	-0.0117	--	0.1144	0.0522	0.0605	0.0190	--	--
	4	0.0093	0.0388	--	0.0497	0.0074	0.0119	0.0130	0.0183	--
	5	--	0.1035	0.1939	0.0076	--	0.0162	0.0249	0.0792	0.3848**
	6	0.017	-0.0171	-0.089	--	-0.0275	0.0299	--	--	-0.0397
	7	--	-0.0286	0.2100	0.1252	-0.0075	--	0.0410	--	0.4031**
	8	0.0208	0.0761	0.1544	-0.0346	0.0664	0.0260	-0.0141	0.0272	0.3405**
	9	0.0493	0.0738	0.2165	--	--	--	0.0494	-0.0221	0.0560
Plant height (cm)	1	-0.0052	--	--	--	0.0019	-0.0025	0.0017	0.0023	--
	2	0.0121	0.0096	-0.0134	0.0557	0.0182	0.0110	--	--	-0.0061
	3	-0.0035	-0.0149	--	0.0628	-0.0131	-0.0050	0.0217	--	0.4377**
	4	0.005	-0.0060	--	-0.1470	-0.0019	0.0154	-0.0038	-0.0637	0.2060*
	5	--	0.0131	0.0017	0.0428	--	0.0283	-0.0101	-0.0001	0.0624
	6	-0.0601	-0.0987	0.0800	--	0.0090	0.0586	--	--	--
	7	--	0.0050	-0.0530	-0.0889	0.0158	--	0.0050	--	0.3719**
	8	0.0114	-0.0319	-0.0219	0.0979	-0.0126	-0.0256	0.0276	-0.0135	-0.0547
	9	-0.0511	0.0067	-0.0030	--	--	--	-0.0446	-0.0221	--
Number of matured pods/plant	1	0.0200	--	--	--	0.1612	0.0970	0.0557	0.0442	0.2476**
	2	0.0098	0.0038	-0.1699	0.1004	0.3067	0.1545	--	--	0.3223**
	3	0.1686	-0.0070	--	-0.0856	0.4092	0.2024	-0.0155	--	0.2139**
	4	0.0026	0.0032	--	0.0005	0.0354	0.0182	-0.0023	0.0052	0.2084*
	5	--	0.0447	0.0190	0.0896	--	0.0842	-0.0814	0.0952	--
	6	-0.0680	-0.0023	-0.0524	--	-0.1695	0.0262	--	--	-0.4034**
	7	--	0.0158	-0.0020	-0.0101	0.057	--	0.0048	--	0.0024
	8	0.0794	0.1161	0.0989	-0.0295	0.2298	0.0337	0.0576	0.0173	0.2651**
	9	0.0071	-0.0513	-0.0061	--	--	--	0.0103	-0.0079	--
Number of immature pods/plants	1	0.0175	--	--	--	0.0354	0.0589	0.0118	-0.0020	-0.1123
	2	0.0233	-0.0187	-0.0713	0.0377	0.0957	0.1901	--	--	0.1849*
	3	-0.0033	-0.0340	--	0.0126	-0.0777	-0.1571	0.0239	--	-0.0109
	4	0.0000	0.0005	--	0.0050	-0.0246	-0.0478	-0.0074	-0.0046	0.0019
	5	--	-0.0169	-0.0079	-0.0626	--	-0.0947	0.0309	0.0064	-0.0046
	6	-0.0099	-0.0003	0.0250	--	0.0115	-0.0744	--	--	-0.0936
	7	--	0.0183	0.0825	0.0033	0.0355	--	-0.0251	--	--
	8	-0.0217	-0.0543	-0.0237	0.0367	-0.0206	-0.1404	0.0416	0.0001	-0.1155
	9	-0.0375	-0.0126	-0.0022	--	--	--	0.0232	0.0025	--
Kernel yield/plant (g)	1	0.0002	--	--	--	-0.0663	-0.0386	-0.1921	-0.1581	0.7905**
	2	0.0427	0.0121	-0.0469	-0.2065	-0.2928	-0.2046	--	--	--
	3	0.2861	-0.0802	--	0.3057	-0.0336	-0.1346	0.8847	--	0.8655**
	4	-0.2936	0.0454	--	-0.0112	0.0282	-0.0669	-0.4342	-0.1918	0.2895**
	5	--	-0.0091	0.0042	-0.0078	--	-0.0107	0.0329	-0.0034	0.0147
	6	-0.0051	-0.0267	-0.0184	--	-0.0386	-0.0124	--	--	--
	7	--	0.0597	-0.0361	0.0104	-0.0154	--	-0.1850	--	0.2206**
	8	0.0116	-0.0235	0.0098	-0.0302	-0.0268	0.0317	-0.1070	-0.0710	0.6414**
	9	-0.0287	0.0248	0.0263	--	--	--	0.1153	0.0402	0.4251**
Harvest index (%)	1	0.0977	--	--	--	0.2511	-0.0307	0.7537	0.9156	0.9301**
	2	0.1474	-0.1920	-0.3859	0.0218	0.2188	0.0551	--	--	--
	3	0.0343	-0.0126	--	0.0325	0.0308	0.0076	0.0607	--	--
	4	0.2670	0.0154	--	0.3249	0.1102	0.0719	0.3315	0.7503	0.7288**
	5	--	0.1109	0.3132	-0.0019	--	-0.0522	-0.0796	0.7669	0.9314**
	6	-0.3521	-0.4456	-0.0018	--	-0.2549	-0.1434	--	--	--
	7	--	-0.0483	0.2020	0.3175	-0.0498	--	0.2412	--	--
	8	-0.1682	0.3958	0.1769	-0.1389	0.0758	-0.0005	0.6665	1.0037	0.9097**
	9	0.2436	-0.2439	-0.0878	--	--	--	0.3002	0.8611	0.8927**

(--) column shows non-significant cross for that of particular character.

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