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Genetic variability studies in F_2 and F_3 populations of three crosses of groundnut (*Arachis Hypogaea* L.)

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Abstract
F_2 and F_3 populations of three crosses *viz.*, TMV-2 × ICGV-91114, TMV-2 × TG-69 and TMV-2 × ICGV-00350 were assessed to estimate the nature and magnitude of genetic variability during *kharif* and *summer*-2017. Higher magnitudes of range and standardized range were observed for all the traits in all the three crosses. The higher estimates of GCV and PCV noticed for pods plant^{-1}, pod yield plant^{-1}, kernel yield plant^{-1}, branches plant^{-1} and sound mature kernel percent which indicated the presence of adequate variability for these traits suggesting the ample opportunity for selection. The close correspondence between estimates of GCV and PCV indicated lesser influence of environment on traits like plant height, branches plant^{-1} and days to first flowering in all the three crosses which is amply reflected by high broad sense heritability along with high expected GAM, suggesting the involvement of additive gene action in controlling these traits and hence, selection will be effective for these traits. A decreasing trend was observed for range, standardized range for both GCV and PCV from F_2 to F_3 generation, which explains the substantial decrease of variability in F_3 generation due to selection practiced in F_2 generation.

Keywords: Genetic variability, GCV, PCV, heritability in broad sense, GAM, additive genetic effect

Introduction
Groundnut (*Arachis hypogaea* L.), known as king of oilseeds, is an important oilseed crop in the world as well as in India. It is a highly self-pollinated crop belonging to the family Fabaceae and an allotetraploid with a chromosome number of 2n=4x=40, having 'A' and 'B' genomes, contributed by diploid progenitors *A. duranensis* and *A. ipaensis*, respectively. The hybridization between these diploid progenitors might have occurred about 3,500 years ago which lead to the origin of cultivated groundnut (Kochert *et al*., 1996) [10]. The seed contains about 40-54 percent oil, 25-28 percent protein and 18 percent carbohydrates in addition to minerals and vitamins. Groundnut is the third largest oilseed crop produced in the world and second largest in India. It is grown in 90 countries around the world in an area of 23.4 million hectares with 42 million tonnes production and 17.96 quintals of productivity per hectare. Groundnut is cultivated in India in an area of 5.25 million hectares with a production of 9.47 million tonnes and productivity of 18.04 quintals per hectare. Karnataka is the fourth largest producer of groundnut in India with productivity 7.32 quintals per hectare, after Gujarat, Andhra Pradesh and Tamil Nadu, respectively (Anon., 2017) [2]. Current productivity level of groundnut in Karnataka (0.73 t ha^{-1}) is less than half of national average (1.8 t ha^{-1}) (Anon., 2017) [2]. TMV-2, the variety developed and released in 1940 (78 years back) is still ruling despite other varieties better than TMV-2 with higher pod yield. Traders or oil mills still prefer TMV-2 variety for oil extraction because of its even-sized pods and kernels. However, the government has denotified the variety and hence it is not available in the official seed chain. There is an urgent need to develop a variety with yield potential better than that of TMV-2 but with pod and kernel type of TMV-2 so that the gap between the current productivity level of groundnut in Karnataka and national average can be reduced. Availability of natural and/or generated genetic variability is a prerequisite for any crop improvement as it provides a wide scope for the selection. The effectiveness of selection depends on the nature, extent, and magnitude of genetic variability present in the material and the degree of heritability. Existing variability has been exploited to the maximum extent by selection; thus there is a need to generate new variability in segregating populations by crossing among best available genotypes. In the present investigation carried out to create desirable variation by crossing TMV-2 × ICGV-91114, TMV-2 × TG-69 and TMV-2 × ICGV-00350 so that selection can be carried out after evaluating them for genetic variability and heritability of Characters.

Material and Methods

The experiment was carried out during *kharif*- 2017 at the field unit of ARS, Chintamani and National Seed Project, J Block, UAS, GKVK, Bengaluru. The crop was grown by following all the agronomic practices as per the package of practices recommended for Eastern Dry Zone of Karnataka (Anon., 2016) [1]. The material for the present investigation consisted of F_2 and F_3 populations of three connected crosses *viz*., TMV-2 × ICGV-91114, TMV-2 × TG-69 and TMV-2 × ICGV-00350 where, TMV-2 was the common female parent, which is comparatively low yielding but has desirable pod type and kernel type. It was crossed to the three high yielding varieties, ICGV-91114, TG-69 and ICGV-00350. Parent material was obtained from AICRP on Groundnut, ARS, Chintamani.

The F_2 plants derived from each of the three connected crosses and their parents were grown in plots of 18 m^2 area with a spacing of 0.3×0.2 m. The parents were evaluated in Randomised Block Design with three replications. Both the parents and F_2 population were evaluated during kharif- 2017 at the field unit of ARS, Chintamani. In total, 189 F_2 plants from cross TMV-2 × ICGV-91114, 196 from cross TMV-2 × TG-69 and 200 F_2 plants from cross TMV-2 × ICGV-00350 were available for recording observations.

The top 25 genotypes bearing TMV-2 pod type were selected based on kernel yield from each of the three crosses. The selected F_2 plants were forwarded to F_3 and evaluated on plant-to-row progeny basis in Augmented Design along with checks TMV-2, GKVK-5 and KCG-6 during *summer*-2017 at experimental field unit of National Seed Project, UAS, GKVK, Bengaluru. The data was recorded on individual plants in the F_2 generation and on five plants randomly selected from each of the parents in each of the three replications.

In the F_3 generation, five plants randomly selected from each of the family or progeny row, and checks from each block were considered for recording the observations. The genotypic and phenotypic co-efficient of variations was computed as suggested by Robinson *et al.*, (1949) [13]. Heritability and genetic advance were worked out as per the method outlined by Hanson *et al.*, (1956) [6]. The Analysis of variance was performed following Augmented Design as suggested by Federer (1961) [4], using WINDOSTAT 8.5 version for F_3 population.

Results and Discussion

Mean performance of parents

The results revealed that the parents differed significantly for days to first flowering, pods plant^{-1}, pod yield plant^{-1} and kernel yield plant^{-1} indicating the diverse nature of parents used in hybridization. The mean performance of the parents ranged from 31.13 (ICGV-91114) to 36.53 (ICGV-00350) for days to first flowering, and from 16.20 (ICGV-00350) to 22.60 (ICGV-91114) for pods plant^{-1}. The mean values for pod yield plant^{-1} ranged from 10.67 (ICGV-00350) to 15.33 (TMV-2) and for kernel yield plant^{-1} from 6.93 (ICGV-00350) to 10.03 (TG-69). However, no significant difference was noticed for plant height, branches plant^{-1}, shelling percent and sound mature kernel percent, among the four parents (Table 1).

Table 1: Mean performance of pod yield and its attributes for parents used in the crosses

Parents	Plant height (cm)	Branches plant^{-1}	Days to first flowering	Pods plant^{-1}	Pod yield plant^{-1} (g)	Kernel yield plant^{-1} (g)	Shelling %	SMK %
TMV-2	31.07	4.67	34.20	22.60	15.33	9.00	57.25	70.80
ICGV-91114	30.47	4.73	31.13	20.53	14.70	9.83	67.44	81.71
TG-69	30.07	4.53	33.40	19.80	14.80	10.03	67.87	83.43
ICGV-00350	32.13	4.73	36.53	16.20	10.67	6.93	65.40	72.93
CD @ 5%	2.29	0.61	0.88	1.63	2.28	2.42	9.68	16.86
CD@ 1%	3.47	0.93	1.33	2.47	3.46	3.66	14.67	25.55
Overall mean of parents	30.94	4.67	33.82	19.78	13.88	8.95	64.49	77.22

Analysis of Variance

Significant mean sum of squares noticed for all the traits due to progenies suggested the existence of significant variability among the progenies for all the traits in all the three crosses except for shelling percent in cross TMV-2 × ICGV-91114, branches plant^{-1} in cross TMV-2 × TG-69 and for sound mature kernel percent in cross TMV-2 × ICGV-00350 (Table 2). This variability noticed can be attributed to the segregation of genes as F_3 is an early segregating generation.

Further, the significant mean sum of squares due to checks vs. progenies (between F_3 progeny rows) observed for all the traits in F_3 progenies of all the three crosses except for traits plant height, kernel yield plant^{-1} in crosses TMV-2 × ICGV-91114 and TMV-2 × ICGV-00350, for sound mature kernel percent in crosses TMV-2 × ICGV-91114 and TMV-2 × TG-69 and for branches plant^{-1}, pods plant^{-1} in cross TMV-2 × TG-69, suggested the presence of adequate variability between the progenies as well. The significant differences were also noticed between the checks for branches plant^{-1}, days to first flowering and shelling percent in all the three crosses (Table 2). The significant variability found among and also between the F_3 progenies adequately provided statistical validity for evaluating these progenies further for pod yield and its component traits in all the three crosses.

Table 2: ANOVA for pod yield and its attributing traits in F_3 generation of three crosses C_1, C_2 and C_3

Source of variation	Crosses	Blocks	Progenies + Checks	Checks	Progenies	Checks vs. Progenies	Error
Degrees of freedom		7	27	2	24	1	14
Plant height(cm)	C_1	20.02**	11.12*	9.88	13.82*	13.64	4.04
	C_2	16.58*	23.79 ***	9.88	22.80 ***	116.27***	4.038
	C_3	8.80	16.82 **	9.88	16.78 **	17.88	4.038
Branches plant^{-1}	C_1	0.78	1.40**	8.65***	0.78*	3.91**	0.29
	C_2	0.78	1.20 **	8.65 ***	0.67	1.06	0.29
	C_3	0.74	1.59 ***	8.65 ***	0.99*	3.67 **	0.29
Days to 50% flowering	C_1	5.14	8.55**	21.29**	5.87*	55.38***	2.48

	C_2	13.95**	8.52 **	21.29 **	8.49 *	53.32 ***	2.48
	C_3	25.96 ***	12.56 **	21.29 **	10.24 **	204.50 ***	2.48
Pods plant^{-1}	C_1	111.83*	209.43***	84.16	221.54***	937.21***	26.92
	C_2	145.08 **	126.84 **	84.16	175.94 ***	34.34	26.92
	C_3	110.02 *	243.41 ***	84.16	254.62 ***	1048.04 ***	26.92
Pod yield plant^{-1} (g)	C_1	74.64*	141.61***	42.13	160.59***	319.79**	24.32
	C_2	67.70*	79.49 *	42.13	95.36 **	159.71 *	24.32
	C_3	104.47**	161.47 ***	42.13	191.14 ***	331.82 **	24.32
Kernel yield plant^{-1}(g)	C_1	34.55	57.35*	5.45	70.63**	31.52	17.01
	C_2	37.90	38.00	5.45	42.57 *	205.98 **	17.01
	C_3	66.35 *	66.07 **	5.45	90.48 **	13.19	17.01
Shelling %	C_1	41.65	71.57**	244.01***	25.77	842.25***	15.46
	C_2	27.84	86.58 ***	244.01 ***	39.32 *	825.71***	15.46
	C_3	78.39 **	106.36 ***	244.01 ***	48.89 *	1483.87 ***	15.46
SMK %	C_1	48.99	104.91**	25.33	118.03***	49.54	21.38
	C_2	64.24 *	71.92 *	25.33	87.36 **	1.61	21.38
	C_3	33.05	50.05 *	25.33	47.52	149.01 *	21.38

*: Significant at P=0.05, **: Significant at P=0.01 and ***: Significant at P=0.001

C_1 - TMV-2×ICGV-91114, C_2 - TMV-2×TG-69 and C_3 - TMV-2× ICGV-00350

Genetic variability studies in F_2 and F_3 populations of the three crosses

On comparing the trait means of F_2 population with the F_3 progeny means, a large shift of trait mean values was observed from F_2 to F_3 generation for all the traits in all the three crosses as expected (Table 3). This shift can be accountable to the selection practiced in F_2 population based on TMV-2 pod type and kernel yield and the correlated response of other traits to the selection.

Among the crosses in F_2 population mean performance of cross TMV-2 × ICGV-00350 was higher for branches plant^{-1}, days to first flowering, pods plant^{-1}, pod yield plant^{-1} and kernel yield plant^{-1}, indicating that, this cross is better performing compared to other two crosses. Among the three crosses, cross TMV-2 × TG-69 manifested higher mean values for plant height, shelling percent and sound mature kernel percent. However in F_3 progenies of cross TMV-2 × ICGV-00350 were late maturing than the other two crosses studid in this investigation. TMV-2 × ICGV-91114 and TMV-2 × ICGV-00350 cross F3 progenies had high number pods plant^{-1}, higher pod yield plant^{-1} and kernel yield plant^{-1} than cross TMV-2 × TG-69, but TMV-2 × ICGV-91114 cross F3 progenies recorded low readings for shelling percent and sound mature kernel percent were than TMV-2 × TG-69 and TMV-2 × ICGV-00350 (Table 3).

Table 3: Estimates of mean, range and standardized range for pod yield and its attributing traits in F_2 and F_3 population of three crosses.

Traits	Crosses	Mean		Range				Standardized range	
				Minimum		Maximum			
		F_2	F_3	F_2	F_3	F_2	F_3	F_2	F_3
Plant height(cm)	C_1	29.89	39.51	20.00	30.50	45.00	47.40	0.84	0.43
	C_2	31.68	37.49	19.00	29.00	46.00	44.00	0.85	0.40
	C_3	31.39	41.77	21.00	34.80	40.00	49.60	0.61	0.35
Branches plant^{-1}	C_1	4.07	5.95	1.00	4.00	6.00	7.50	1.23	0.59
	C_2	4.20	5.67	3.00	4.20	7.00	7.00	0.95	0.49
	C_3	4.27	5.93	3.00	3.67	7.00	7.60	0.94	0.66
Days to 50% flowering	C_1	32.84	43.96	29.00	40.00	37.00	49.00	0.24	0.20
	C_2	33.77	43.92	29.00	40.00	38.00	51.00	0.27	0.25
	C_3	35.40	45.92	33.00	42.00	37.00	51.00	0.11	0.20
Pods plant^{-1}	C_1	12.00	35.53	1.00	10.00	29.00	60.00	2.33	1.41
	C_2	13.22	28.46	3.00	3.60	39.00	59.60	2.72	1.97
	C_3	15.13	36.03	5.00	8.67	36.00	70.60	2.05	1.72
Pod yield plant^{-1}	C_1	8.74	28.83	0.60	6.26	20.00	49.64	2.22	1.50
	C_2	8.22	20.11	1.50	1.70	23.00	41.04	2.62	1.96
	C_3	11.10	28.92	3.00	5	31.00	55.02	2.52	1.73
Kernel yield plant^{-1}	C_1	5.81	19.48	0.50	3.52	15.50	33.50	2.58	1.54
	C_2	5.85	13.77	1.00	1.02	16.00	26.36	2.56	1.84
	C_3	7.43	18.87	1.50	3.13	22.00	36.78	2.76	1.78
Shelling %	C_1	65.05	67.36	22.22	57.43	89.66	75.29	1.04	0.27
	C_2	70.81	67.45	45.45	57.16	88.89	77.36	0.61	0.30
	C_3	64.35	64.64	25.00	48.42	85.71	83.66	0.94	0.55
SMK %	C_1	80.29	84.29	0.00	48.07	100.00	100.00	1.25	0.62
	C_2	86.97	85.94	0.00	64.15	100.00	98.00	1.15	0.39
	C_3	79.15	82.81	0.00	68.31	100.00	93.63	1.26	0.31

C_1 - TMV-2×ICGV-91114, C_2 - TMV-2×TG-69 and C_3 - TMV-2× ICGV-00350

High magnitudes of both range and standardized range were noticed for all the traits in both F_2 and F_3 populations of all the three crosses except for days to first flowering. Highest standardized range was observed for traits like pods plant^{-1}, pod yield plant^{-1} and kernel yield plant^{-1}. But there was significant decreasing trend of standardized range from F_2 to

F_3 generation was noticed for all traits except for days to first flowering in all three crosses (Table 3), which explains the substantial decrease of variability in F_3 generation due to selection practiced in F_2 generation.

In the present investigation, higher estimates of GCV and PCV were noticed for pods plant^{-1}, pod yield plant^{-1} and kernel yield plant^{-1}, the most important yield traits, in both F_2 and F_3 population of all the three crosses and for branches plant^{-1} and sound mature kernel percent in F_2 population of cross TMV-2 × ICGV-91114 and TMV-2 × ICGV-00350.

In F_2 population, moderate estimates of GCV and PCV were noticed for plant height in all the three crosses, branches plant^{-1} in cross TMV-2 × TG-69, shelling percent in cross TMV-2 × ICGV-91114 and TMV-2 × ICGV-00350 and for sound mature kernel percent in cross TMV-2 × TG-69. However, moderate PCV was observed for plant height in cross TMV-2 × TG-69, branches plant^{-1} in all the three crosses and for sound mature kernel percent in cross TMV-2 × ICGV-91114 in F_3 population. Low magnitudes of GCV and PCV noticed for days to first flowering suggested less variability expressed for this trait in both F_2 and F_3 populations of all the three crosses (Table 4). Similar findings were reported by Jayalakshmi *et al.* (1998) [8], Rudraswamy *et al.* (1999) [14] and Dolma *et al.* (2010) [3] for pod yield and kernel yield plant^{-1}. The results for plant height at harvest (moderate GCV) and for days to first flowering (low GCV) were in agreement with the results reported earlier by Mohan *et al.* (2012) [12]. A decreasing trend was observed for both GCV and PCV from F_2 to F_3 generation, which again reiterated the substantial decrease of variability in F_3 generation due to selection practiced in F_2 generation. Further close correspondence between estimates of GCV and PCV indicated the lesser influence of environment on growth traits like plant height, branches plant^{-1} and days to first flowering in all the three crosses which is amply reflected by high broad sense heritability along with high expected GAM (except days to first flowering) in both F_2 and F_3 populations. On the contrary, wider differences between the estimates of GCV and PCV indicated larger influence of environment for the expression of yield traits like pods plant^{-1}, pod yield plant^{-1} and kernel yield plant^{-1}, which is amply reflected by comparatively low broad sense heritability in F_2 and F_3 populations of cross TMV-2 × ICGV-91114 and TMV-2 × TG-69. However, high magnitude of broad sense heritability accompanied with high expected GAM was recorded for pods plant^{-1}, pod yield plant^{-1} and kernel yield plant^{-1} in F_2 and F_3 populations of cross TMV-2 × ICGV-00350 indicating that selection for these traits would be effective in this population. Similar results are reported by Meta and Monpara (2010) [11] for plant height, Zaman *et al.* (2011) [15] for branches plant^{-1} and days to first flowering, John and Raghava (2014) [9] for pods plant^{-1}, pod yield plant^{-1} and kernel yield plant^{-1}.

Table 4: Estimates of parameters specifying variability for pod yield and its attributing traits in F_2 and F_3 population of the three crosses

Traits	Crosses	PCV%		GCV%		h^2 (BS)		Expected GAM	
		F_2	F_3	F_2	F_3	F_2	F_3	F_2	F_3
Plant height(cm)	C_1	15.67	7.91	12.66	6.06	65.31	58.63	21.08	9.55
	C_2	15.89	10.34	13.47	8.84	71.88	63.12	23.53	15.57
	C_3	14.16	8.12	12.17	6.54	73.97	64.87	21.57	10.85
Branches plant^{-1}	C_1	25.75	12.80	20.79	9.02	65.18	49.63	34.58	13.09
	C_2	26.38	12.62	18.03	8.29	46.70	43.12	25.38	11.21
	C_3	28.73	14.14	21.08	10.81	53.85	48.46	31.86	17.02
Days to 50% flowering	C_1	5.90	4.81	5.05	3.21	73.19	44.44	8.89	4.40
	C_2	6.78	5.58	5.97	4.27	77.51	58.64	10.82	6.74
	C_3	3.86	5.77	4.64	3.29	72.64	64.67	5.78	7.69
Pods plant^{-1}	C_1	40.51	33.40	31.58	30.04	60.78	50.89	50.72	45.65
	C_2	45.45	37.54	33.45	32.82	54.17	46.42	50.72	49.10
	C_3	38.77	35.13	33.72	32.04	75.64	63.20	60.42	60.20
Pod yield plant^{-1}	C_1	44.17	35.39	30.98	28.66	42.11	36.63	38.31	25.87
	C_2	44.68	40.38	32.07	24.08	29.05	23.10	26.74	22.48
	C_3	49.48	38.18	41.44	34.16	70.12	60.06	71.48	62.97
Kernel yield plant^{-1}	C_1	48.92	35.72	31.12	28.77	40.46	34.85	40.78	37.72
	C_2	46.51	41.07	28.09	20.03	18.55	16.79	17.77	15.58
	C_3	54.48	40.97	43.76	34.68	64.50	51.65	72.40	60.47
Shelling %	C_1	19.15	7.13	17.27	12.9	81.26	16.52	32.06	2.43
	C_2	11.22	8.04	9.22	5.54	67.63	47.45	15.63	7.86
	C_3	16.51	9.16	14.90	6.84	81.41	55.85	27.69	10.53
SMK %	C_1	26.96	10.48	26.31	8.92	95.24	72.57	52.89	15.66
	C_2	16.51	9.01	14.95	7.23	81.93	64.36	27.87	11.95
	C_3	28.12	7.31	27.69	4.72	96.94	41.70	56.15	6.28

C_1 - TMV-2×ICGV-91114, C_2 - TMV-2×TG-69 and C_3 - TMV-2× ICGV-00350

The parents used in hybridization were diverse in nature with respect to traits, days to first flowering, pods plant^{-1}, pod yield and kernel yield plant^{-1}. The mean performance of cross TMV-2 × ICGV-00350 was comparatively greater than the other two crosses for yield traits like pods plant^{-1}, pod yield plant^{-1} and kernel yield plant^{-1} in both F_2 and F_3 populations, indicating that this cross was high yielding compared to other two crosses. Moderate to high estimates of GCV and PCV along with high heritability and high expected GAM were observed for plant height, branches plant^{-1} and shelling percent suggesting that these traits are governed by additive gene action, hence selection on these traits will be effective to enhance productivity of groundnut.

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