Plant Archives Vol. 17 No. 2, 2017 pp. 1353-1360 ***ISSN 0972-5210***

VARIABILITY, HERITABILITY AND ASSOCIATION STUDIES IN F_4 AND F_5 GENERATION FOR TRAITS RELATED TO WATER USE EFFICIENCY AND YIELD TRAITS IN GROUNDNUT (*ARACHIS HYPOGAEA* L.)

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Abstract

In the present study, F_4 and F_5 populations were evaluated to study the genetic variability for traits related to WUE, pod yield and its attributing characters. Higher estimates of PCV and GCV were recorded for number of pods per plant, kernel yield per plant and pod yield per plant indicating the presence of sufficient variability for these traits. High heritability accompanied with high GAM was observed for plant height, pods per plant, kernel yield per plant, pod yield per plant and moderate GAM for SCMR and SLA indicating the involvement of additive gene action in controlling these traits. Pods per plant, kernel yield per plant and SCMR exhibited strong positive association with pod yield, whereas SLA exhibited negative association. This indicated selection for higher SCMR, pods per plant and kernel yield per plant and selection for lower SLA will lead to improvement in yield. Kernel yield exerted highest positive direct effect on pod yield; highest indirect effect was exhibited by SCMR and pods per plant through kernel yield per plant. Thus, selection of genotypes based on the kernel yield, SCMR and SLA will be more effective for developing high yielding coupled with high water use efficient genotypes.

Key words : Water use efficiency, groundnut, F_4 and F_5 generation.

Introduction

Groundnut (*Arachis hypogaea* L.), is one of the most important oilseed legume crop, grown in arid and semi-arid regions of the world. The most important factor for plant breeding is genetic variation in the desired characteristic feature. Therefore, new variability is generated by crossing among best available genotypes and selection is carried out in segregation generation.

Gain under direct selection for pod yield in groundnut is low and slow as pod yield is not only polygenically controlled, but also influenced by its component characters (Alam *et al*., 1985). The knowledge of existing variability and degree of association between pod yield and its contributing characters and their relative contribution to pod yield is essential for developing high yielding genotypes. Heritability and genetic advance is a useful tool for breeders in determining amount of genetic variation present in crop. Correlation and path analysis is helpful to determine the magnitude of association among the characters and relative contribution of them on pod yield.

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Groundnut is grown mainly under rainfed condition worldwide where drought is a major abiotic constraint affecting productivity and quality of groundnut. Therefore, breeding for drought resistance is an important strategy in alleviating the problem and offers the best long-term solution. Selection in segregating population has been a standard approach for developing cultivars with improved stress tolerance.

Water Use Efficiency (WUE) is one such trait that can contribute to productivity under drought. It is rather difficult to use WUE as a selection trait in routine groundnut breeding programme for drought tolerance because of difficulties associated with its measurement under field conditions (Nageshwara Rao *et al*., 2001) and also high genotype × environment interaction.

More rapid progress in this aspect may be achieved by using physiological traits (Nigam *et al*., 2008) such as specific leaf area (SLA) and SPAD chlorophyll meter reading (SCMR). Specific leaf area exhibits negative significant relationship with WUE (Wright *et al*., 1994; Nageshwara Rao and Wright, 1994). Strong positive correlation of WUE with Soil Plant Analytical Development (SPAD) was recorded (Jongrungklang *et al*., 2008). Both SLA and SCMR could be used as surrogate traits for WUE (Wright *et al*., 1994; Nageswara Rao and Wright, 1994; Sheshshayee *et al*., 2006; Nigam *et al*., 2008).

Keeping all the above points in view, an attempt has been made to study the genetic variability and interrelations for yield and its attributing characters and water use efficiency related traits in F_4 and F_5 generation of a cross GKVK-16 × KCG-2 in groundnut.

The present study was undertaken with the following objectives :

1. To assess variability for traits related to water use efficiency and pod yield in F_4 and F_5 generations.

2. To identify genotypes superior for pod yield, SCMR and SLA in F_5 generation.

Materials and Methods

The experimental material consist of F_4 and F_5 generation of a cross GKVK-16 × KCG-2 with 49 and 66 families in each generation, respectively. The experiment was laid out in an augmented design during *kharif*, 2014 for F_4 generation and summer 2015 for F_5 generation at University of Agricultural Sciences, Bengaluru.

Observations on physiological traits like SCMR and SLA were recorded at 8.00-9.00 am at 70 days after sowing. The second to third leaves from the top of the main stem of each plant was used for recording SCMR and SLA. SCMR was measured by a Minolta hand held portable SCMR meter (SPAD- 502 Minolta, Tokyo, Japan), using four leaflets per sample. The same samples were further used for measuring leaf area, using a leaf area meter. Then the leaves were oven-dried at 70°C for 3 days and leaf dry weight was determined. The SLA was computed using the formula below and expressed as cm^2/g.

$$SLA\left(cm^2/g\right)=\frac{\text{Leaf Area}\left(cm^2\right)}{\text{Leaf dry weight}\ (g)}$$

Other observations were recorded on days to first flowering, plant height (cm), primary branches per plant, pods per plant, pod yield per plant (g), kernel yield per plant (g), shelling percentage and sound mature kernel (SMK) percentage. Observations were recorded on all the F_4 and F_5 plants except border plants in each cross for yield and physiological related traits. Genotypic and phenotypic coefficient of variability (GCV and PCV) was worked out as per Burton and De Vane (1953). Heritability and genetic advance were computed according to Johnson *et al*. (1955). Mean, range and correlation co-efficient were computed according to Sunder Raj *et al*. (1972) and Wright (1921), Dewey and Lu (1959) for path coefficient analysis.

Results and Discussion

Analysis of variance was carried out for growth, WUE related traits, yield and its component characters in F_4 and F_5 generations of GKVK-16 × KCG-2 and is presented in table 1. Mean sum of squares of progenies exhibited highly significant difference for all the traits under study except pods per plant in F_4 generation and days to first flowering in F_5 generation. Analysis of variance for both progenies and checks displayed significantly greater difference for characters like days to first flowering, plant height, branches per plant, SCMR, SLA, pod yield per plant, kernel yield per plant and sound mature kernel *per cent* except pods per plant in F_4 generation. Mean sum of squares of checks *versus* progenies also exhibited greater significant difference for all the characters except days to first flowering and pods per plant. Less variation was observed for days to first flowering, plant height, branches per plant and kernel yield for mean sum of squares of progenies in F_5 generation and there is no significant variation for shelling *per cent* in both the generations. The result revealed significant difference for most of the characters among progenies except for traits like pods per plant and for shelling *per cent* indicating presence of sufficient amount of genetic variability for all other traits in the population.

The estimates of mean performance, range, PCV (%) and GCV (%), Heritability (bs) and Genetic Advance as *per cent* mean (GAM) of various characters are given in the table 2.

Variability refers to the presence of genotypic and phenotypic differences among the individuals of plant population. Variability may be due to genetic constitution of the individuals of a population or due to environment in which they are grown. Selection is effective only when there is genetic variability among the individuals in a population. Hence, insight into the magnitude of genetic variability present in a population is of paramount importance to plant breeders. The total variability in the material cannot be inferred only by mean and range values. Hence, actual variance has been estimated for the characters to know the existing variability. Heritability

Table 1 : Analysis of variance for traits related to growth, water use efficiency, pod yield and its component characters in F_4 and F_5 populations of groundnut in the cross GKVK-16 × KCG-2.

Source of variation	Gn	Df	DFF	Plant height (cm)	Branches/ plant	SCMR	SLA (cm^2/g)	Pods/ plant	Pod yield/ plant (g)	Kernel yield /plant (g)	Shelling per cent	SMK (%)
Blocks (eliminating check+var)	F_4	6	0.492	5.436	0.035	1.253	43.525	21.33	11.177	0.306	19.707	27.879
	F_5	5	4.491*	19.28	0.089	2.239*	50.3	2.003	0.43	10.6	56.89	2.554
Progenies + Checks	F_4	51	5.39***	26.59***	0.17***	9.85***	347.36***	70.64	49.95**	21.78***	48.4	128.89**
	F_5	68	2.095*	65.88**	0.377**	9.374**	370.13**	62.27*	16.44**	50.4**	212.19	37.61**
Checks	F_4	2	12.3***	13.35*	0.01	66.52***	333.7**	220.64	13.88	19.45***	212.68*	42.04
	F_5	2	1.307	180.22**	1.55**	80.49**	818.68**	0.92	5.104	27.57*	592.28	9.25*
Progenies	F_4	48	5.2***	25.89***	0.123**	6.88**	322.75***	65.83	48.33***	21.14***	39.82	113.4**
	F_5	65	1.32	60.83**	0.34*	7.22**	283.52**	45.99**	12.06**	68.98**	201.94	22.34**
Checks *vs.* Progenies	F_4	1	0.89	86.83***	2.99***	39.13***	1555.61***	1.49	199.83***	57.42***	131.86	1045.94***
	F_5	1	53.77**	165.34**	0.023	6.91**	1102.85**	1242.7**	323.58**	100.01*	118.7	1087.17**
Error	F_4	12	0.754	2.237	0.021	1.546	5.31	64.08	6.51	0.1	34.52	24.94
	F_5	10	0.56	13.68	0.089	0.37	3.32	10.76	3.2	2.6	179.63	2.19

*Significant at 0.05 probability level. ** Significant at 0.01 probability level. *** Significant at 0.001 probability level. Df: Degrees of freedom, DFF: Days to first flowering.

and genetic advance are other important selection parameters. Heritability estimates along with genetic advance are normally more helpful in predicting the gain under selection than heritability estimate alone, it is not necessary that a character showing high heritability will also exhibit high genetic advance (Johnson *et al*., 1955).

The range of variation is high for plant height (0.76, 1.09), pods per plant (1.24, 1.25), kernel yield per plant (1.69, 1.76), sound mature kernel (1.13, 1.04) and pod yield per plant (1.59, 1.37) both in F4 and F5 generation, respectively. SLA showed relatively high range (0.55, 0.57). This indicates that these traits can be improved through individual plant selection.

Higher estimates of PCV and GCV were observed for pods per plant, kernel yield per plant and pod yield per plant in both the generations. Similar findings of higher estimates of PCV and GCV for kernel yield per plant and pod yield per plant were reported by Giri *et al*. (2009).

The PCV and GCV estimates were moderate for plant height, SLA and SMK percentage in F_4 generation and for primary branches per plant and shelling percent in F_5 generation. Vishnuvardhan *et al*. (2012) reported the moderate estimates of PCV and GCV for plant height and number of primary branches per plant. These estimates indicate the presence of variability for these characters. Therefore, individual plant selection can be practiced for improvement of these traits. Lower estimates of PCV and GCV were recorded for days to first flowering and SCMR. This indicates lower magnitude of variation for these traits.

High broad sense heritability accompanied with high genetic advance as per cent mean was recorded for plant height, pods per plant, kernel yield per plant, SMK and pod yield per plant. This indicates that most likely the heritability is due to additive gene effects and there is lot of scope for improvement of these traits in future breeding programme. Similar results were reported by Nath *et al.* (2002) and Golakia *et al.* (2005) for plant height, pods per plant and pod yield per plant.

High heritability accompanied with low to moderate genetic advance as *per cent* of mean was noticed for traits like days to first flowering, primary branches per plant, SCMR, SLA and shelling per cent. This indicates the presence of non additive gene action and narrow range of variation for these

Table 2 : Estimates of genetic variability parameters for traits related to growth, water use efficiency, pod yield and its component characters in F_4 and F_5 generation for cross GKVK-16 × KCG-2 in groundnut.

Traits	Generation	Range			Standardized Range	GCV (%)	PCV (%)	$h^2_{(bs)}$ (%)	GAM
		Mean	Min	Max					
Days to first flowering	F_4	35.07	32.00	40.00	0.23	6.01	6.50	85.30	11.43
	F_5	45.28	40.00	48.00	0.18	2.41	2.54	90.00	4.70
Plant height (cm)	F_4	37.58	25.20	53.80	0.76	12.26	13.54	82.00	22.87
	F_5	36.53	20.00	60.00	1.09	19.57	21.35	84.00	36.95
Primary branches /plant	F_4	3.86	3.00	4.80	0.47	7.59	9.08	70.00	13.09
	F_5	3.51	3.00	5.00	0.57	15.04	16.61	82.00	28.06
SCMR	F_4	44.01	38.64	51.27	0.29	5.23	5.96	77.00	9.46
	F_5	45.33	39.00	52.30	0.29	5.50	5.93	86.00	10.50
SLA (cm^2/g)	F_4	145.03	106.79	186.18	0.55	10.94	12.39	78.00	19.90
	F_5	159.76	111.20	201.60	0.57	10.00	10.54	90.00	19.54
Pods/plant	F_4	26.92	11.30	44.80	1.24	26.98	30.13	80.20	49.78
	F_5	25.46	9.00	40.83	1.25	25.13	26.64	89.00	48.84
Kernel yield/plant (g)	F_4	11.94	3.65	23.78	1.69	30.31	38.49	62.00	49.16
	F_5	9.71	2.61	17.43	1.76	30.78	36.02	73.00	54.17
Shelling per cent	F_4	63.69	47.85	75.44	0.43	7.41	9.91	56.00	11.43
	F_5	57.71	29.33	76.78	1.27	14.51	18.28	63.00	23.72
SMK (%)	F_4	43.63	16.45	65.84	1.13	19.22	24.41	62.00	31.17
	F_5	70.35	20.00	92.85	1.04	16.53	20.20	67.00	27.88
Pod yield/plant (g)	F_4	18.62	6.85	36.44	1.59	31.90	37.34	73.00	56.15
	F_5	16.60	6.06	28.76	1.37	26.86	28.47	89.00	52.20

traits. This suggests limited scope for further improvement of these characters. Similar results were reported by Makhan *et al*. (2003) in groundnut.

Correlation analysis

The results of the Correlation Coefficient among the traits studied in both F_4 and F_5 generations are shown in table 3.

Phenotypic correlation coefficient revealed that kernel yield per plant (r = 0.979 and r = 0.920 in F_4 and F_5 generation, respectively) and pods per plant (r = 0.902 and r = 0.892 in F_4 and F_5 generation, respectively) having highest positive association with pod yield per plant compared to other characters. Pod yield per plant had significant positive correlation with SCMR, pods per plant, kernel yield per plant and sound mature kernel *per cent* in both F_4 and F_5 generation and for days to first flowering and plant height in F_5 generation. This indicated that improvement in SCMR, pods per plant, kernel yield per plant and sound mature kernel per cent will lead to improvement in yield. These results are in accordance with the reports of Azad *et al*. (2000) and Venkataravana *et al.* (2000). Pod yield per plant showed negative association with SLA (r = -0.162 in F_4 and r = -0.16 in F_5 generation). This indicates that selection for lower SLA leads to higher yields. SCMR and SLA were negatively correlated with each other which indicates that the plants with higher SCMR (higher SCMR higher photosynthetic efficiency) show lower SLA (Leaf ares for transpiration). The results are in confirmation with the reports of Rekha (2005) and Reddy *et al.* (2003). SCMR exhibited highly significant positive association with pods per plant and sound mature kernel per cent in both generations. Therefore, selection for genotypes with high SCMR offers the scope for simultaneous improvement of yield in groundnut as higher SCMR indicate high photosynthetic efficient genotypes. Songsri *et al.* (2008) observed positive correlation between SCMR and pod yield. Specific Leaf Area showed negative non significant association with pods per plant and sound mature kernel per cent and pod yield per plant in F_4 generation and significant negative association with pods per plant (-0.251) in F_5

Table 3 : Phenotypic correlation coefficient for growth, yield and traits related to water use efficiency in F_4 and F_5 generation of a cross GKVK-16 × KCG-2 of groundnut.

Traits	Generation	SCMR	SLA (cm^2/g)	Pods/plant	SMK (%)	Pod yield/plant (g)
Days to first flowering	F_4	-0.267	-0.035	0.108	0.131	0.12
	F_5	0.729**	-0.06	0.728**	0.649**	0.854**
Plant height (cm)	F_4	0.031	-0.021	0.004	0.237	0.138
	F_5	0.268*	-0.146	0.384**	0.317*	0.326**
Primary Branches/plant	F_4	0.361*	-0.025	0.132	0.358*	0.201
	F_5	0.154	-0.239	0.177	0.127	0.117
SCMR	F_4	1	-0.242	0.382**	0.337*	0.510**
	F_5	1	-0.209	0.765**	0.486**	0.906**
SLA (cm^2/g)	F_4		1	-0.094	-0.027	-0.162
	F_5		1	-0.251*	-0.086	-0.16
Pods/plant	F_4			1	0.333*	0.902**
	F_5			1	0.499**	0.892**
Kernel yield/plant (g)	F_4				0.608**	0.979**
	F_5				0.720**	0.920**
SMK (%)	F_4				1	0.566**
	F_5				1	0.619**

*Significant at 0.05 probability level. ** Significant at 0.01 probability level. *** Significant at 0.001 probability level.

Table 4 : Direct and indirect effects of SCMR, SLA and yield attributing traits on pod yield in F_4 generation of groundnut.

Traits	SCMR	SLA (cm^2/g)	Pods/plant	Kernel yield/ plant (g)	SMK (%)	Pod yield/ plant (g) 'r'
SCMR	**0.090057**	0.001023	0.045643	0.378259	-0.00489	0.510**
SLA (cm^2/g)	-0.02182	**-0.00422**	-0.01123	-0.12517	0.000389	-0.162
Pods/plant	0.034435	0.000397	**0.119367**	0.753062	-0.00482	0.902**
Kernel yield/plant (g)	0.040571	0.000629	0.10706	**0.839633**	-0.00881	0.979**
SMK (%)	0.03034	0.000113	0.039703	0.510233	**-0.0145**	0.566**

Residual effect: 0.069 *Significant at 0.05 probability level. ** Significant at 0.01 probability level.
Diagonal values (Bold letters) indicate direct effects of respective characters

generation. Thus, selecting plants with lower specific leaf area will lead to high yield coupled with high water use efficient genotypes as SLA indicates area for transpiration. Koolachart *et al.* (2013) also reported negative relationship between SLA and yield components. Therefore, pod yield can be improved through the selection of genotypes with higher SCMR, pods per plants, kernel yield per plant, SMK per cent and lower SLA.

Path analysis

It was carried out to split the phenotypic correlation coefficient into direct and indirect effects. It measures the direct and indirect contribution of various independent variables on a dependent variable *i.e.* it reveals whether the independent variable is directly contributing to the dependent variable or it is contributing indirectly *via* other component characters.

Path co-efficient analysis was carried out at phenotypic level for five traits with pod yield per plant in F_4 generation. The results are summarized in table 4.

Among the traits studied, kernel yield per plant exhibited highest positive direct effect of 0.839 followed by pods per plant (0.119) on pod yield per plant. Maximum direct effect of kernel yield per plant on pod yield per plant indicates greater contribution of this trait towards

Table 5 : Superior segregants selected for pod yield, kernel yield, SCMR and SLA from F_5 generation of the cross GKVK-16 × KCG-2 in groundnut.

S. no.	Superior plants	Pod yield/plant (g)	Kernel yield/plant (g)	SCMR	SLA (cm^2/g)
1	195-2-7-2	30.8	18.2	46.2	154.1
2	213-2-7-1	34.0	22.3	42.0	145.2
3	213-2-7-8	28.5	17.5	45.2	143.2
4	174-4-3-3	36.2	20.3	45.3	135.0
5	174-4-3-4	33.8	23.2	44.1	145.2
6	213-6-2-2	31.9	21.8	44.0	160.0
7	213-6-2-4	34.8	22.2	48.0	130.2
8	213-6-2-7	39.8	26.8	52.1	135.0
9	138-3-10-8	33.5	18.8	44.8	148.6
10	113-9-7-2	32.2	24.6	43.2	165.0
11	113-9-7-5	25.2	17.0	47.0	163.7
12	209-3-2-4	28.4	18.4	43.6	145.3
13	46-1-7-2	32.2	17.4	44.5	156.2
14	46-1-7-5	38.0	26.7	46.0	154.2
15	113-9-9-2	27.8	18.6	44.3	145.3
16	113-9-9-6	31.8	20.9	46.8	154.7
17	208-4-7-5	28.6	16.7	46.2	160.0
18	208-4-7-6	31.2	22.7	47.9	120.2
19	137-4-2-1	41.4	24.8	48.3	141.1
20	137-4-7-5	25.9	17.6	46.4	143.5
21	213-2-1-1	31.4	17.1	47.2	148.0
22	213-2-1-3	31.8	18.1	48.9	142.3
23	213-2-3-1	28.8	20.3	44.2	150.1
24	213-2-3-3	26.2	16.9	43.2	144.2
25	213-2-3-8	38.8	18.9	52.2	130.0
26	195-1-3-1	37.3	24.0	47.8	143.6
27	195-1-6-2	27.1	19.0	46.5	158.6
28	213-6-10-4	28.1	19.1	47.6	152.0
29	113-9-10-4	27.3	15.7	45.9	150.9
30	213-2-6-1	30.2	18.8	47.7	147.2
31	47-9-10-1	27.5	16.6	48.0	136.8
32	40-1-4-2	34.5	20.6	45.3	142.4
33	40-1-4-3	38.8	26.0	49.3	126.3
34	40-1-4-4	37.6	26.6	48.1	136.5
35	113-3-8-3	25.5	18.8	47.2	149.6
36	46-1-10-1	23.3	16.4	44.8	151.4
37	40-1-5-1	26.6	17.8	46.7	152.3
38	213-2-8-4	30.0	17.7	45.2	152.3
Check	TMV-2	9.0	8.0	32.0	200.0
Parent-1	GKVK-16	15.1	10.2	38.0	188.0
Parent-2 and Check	KCG-2	11.1	8.3	40.0	180.0
	SEm±	3.0	2.6	0.4	3.3
	CD (5 %)	9.4	8.1	1.2	10.4

pod yield per plant. Kumar *et al.* (2012), Khan *et al.* (2000) and John *et al.* (2012) recorded maximum positive direct effect of kernel yield per plant on pod yield per plant. SCMR showed negligible positive direct effect, SLA and SMK showed negligible negative direct effect on pod yield per plant. Maximum positive indirect effect was shown by pods per plant (0.753) through kernel yield per plant followed by sound mature kernel per cent (0.510) and SCMR (0.378) through kernel yield per plant on pod yield per plant, whereas SLA (-0.125) exhibited highest negative indirect effect through kernel yield per plant. The present results are supported by Meta and Monpara (2010). Hence, main emphasis should be given on these traits *viz.,* kernel yield per plant, pods per plant, sound mature kernel per cent and SCMR while selecting genotypes for high yield and water use efficiency. Out of 1056 plants from 66 progenies, 38 superior plants (4%) which were performing better than respective parents and checks for pod yield, kernel yield, higher SCMR and lower SLA were selected and presented in table 5.

In conclusion, the traits kernel yield per plant, pods per plant and SCMR have highest positive association with pod yield per plant. Highest positive direct effect on pod yield per plant is exhibited by kernel yield per plant. Therefore selection based on these component traits is more effective. Thirty eight promising genotypes have been identified based on pod yield, kernel yield, SCMR and SLA. The selected plants should be further forwarded to F_6 generation in multi rows to test their stable performance and for further selection.

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