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Early generation intermating for yield improvement in groundnut (*Arachis hypogaea* L.)

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Summary. Seeds of 4 crosses of groundnut (*Arachis hypogaea* L.), 'Robut 33-1'×'Chico', 'Robut 33-1'×'NC Ac 17090', 'Robut 33-1'×'PI 298115' and 'MK 374' ×'GAUG 1', were irradiated with 30 kR. In the F_1, some branches of each plant were intermated with other plants at random and others selfed in each cross to produce S_2 and F_2 seeds. They were evaluated for pod yield, shelling percentage and 100-kernel weight. The frequency of plants superior to F_1 was much higher in S_2 than in F_2, which was, in general, true for the values of yield and its components. The S_2 and F_2 were advanced to third generation by selfing. The families descending from S_2 showed clear superiority over those from F_2. The reason for such superiority was suggested to be the recombination of genes from the upper and lower ends of the genotypic distribution under intermating.

Key words: Sib mating – Intermating – Selfing – *Arachis hypogaea* – Yield improvement

Introduction

In pedigree breeding for productive pure lines, generations are usually advanced by selfing, particularly in self-pollinated crops like groundnut. This process results in a rapid reduction of heterozygosity, and in the small populations handled by the breeder in each generation, this further narrows down the genetic variability available for selection. This is particularly common in groundnut where producing a large quantity of F_1 seeds is arduous.

Groundnut, however, is an allotetraploid with possibilities of tetrasomic inheritance. The number of complex genotypes in F_2 and later generations segregating for various loci would then be large. Small populations may fail to include useful genotypes with desired traits which occur in low frequencies. It is then worthwhile to examine the potential of mating systems other than selfing, like full-sib mating (intermating), in early generations. The fresh variability generated, if productive, should result in the improvement of such desired traits as yield. The results of such a study on groundnut are reported here.

Material and methods

Four crosses, 'Robut 33-1'×'Chico', 'Robut 33-1'×'NC Ac 17090', 'Robut 33-1'×'PI 298115' and 'MK 374'×'GAUG 1', were chosen for the study. The female parents 'Robut 33-1' and 'MK 374' are high yielding released varieties, both belonging to the Virginia bunch sub-group. Of the male parents, 'Chico', is a collection from Russia belonging to a Spanish bunch sub-group and the earliest to mature (75 days). 'NC Ac 17090' belongs to the Valencia subgroup and 'PI 298115' to the Virginia bunch. Both are resistant to rust. 'GAUG 1' is a Spanish bunch variety grown widely in Gujerat State, India. The genotypes used as parents in the four crosses were thus divergent in origin, sub-group and potential performance. About 30 F_1 seeds of each cross and of their parents were irradiated with a dose of 30 kR from a ^{60}Co source available at the Osmania University, Hyderabad. The seeds were grown and on each plant some branches were used for intermating at random with other plants while others were left to get selfed. The intermated and the selfed progeny plants in each cross constituted the second generation, to be denoted as S_2 and F_2, respectively. They were grown on rows 10 m in length, with an inter-plant spacing of 20 cm, during the rainy season, 1983 at the Indian Agricultural Research Institute, Rajendranagar, Hyderabad. Irradiated parent seeds were also sown in a like manner in contiguous plots.

The performance of the S_2 and F_2 plants was measured by a number of characters at flowering: mean number of days to flowering, plant height, number of primary branches, photo-

Table 1. Frequency of F_2 and S_2 plants in various strata of ranked distribution

Stratum	'Robut 33-1'× 'Chico'				'Robut 33-1'× 'NC Ac 17090'				'Robut 33-1'× 'PI 298115'				'MK 374'× 'GAUG 1'				Overall			
	F_2		S_2		F_2		S_2		F_2		S_2		F_2		S_2		F_2		S_2	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
T_1	5	4.1	20	35.1	5	10.9	17	28.8	5	15.2	17	32.0	3	14.3	12	33.4	18	8.2	66	32.1
T_2	30	24.8	13	22.8	13	28.3	21	35.6	5	15.2	21	39.6	5	23.8	5	13.5	53	24.0	60	29.2
T_3	41	33.9	12	21.1	16	34.8	11	18.6	10	30.3	11	20.8	6	28.6	13	35.1	73	33.1	47	22.9
T_4	45	37.2	12	21.1	12	26.1	10	16.9	13	39.4	4	7.5	7	33.3	7	18.9	77	34.9	33	16.1
Total	121		57		46		59		33		53		21		37		221		206	

F_2 = plants derived by selfing; S_2 = plants derived by intermating in F_1; *n* = number of plants

Table 2. Frequency of S_2 and F_2 progeny showing improvement over the F_1

Cross	Character	r_1	F_2					
			Progeny			Plants		
			n	t	p	n	t	p
'Robut 33-1'× 'Chico'	PY	0.4–34	11	5	45	121	6	5
	SP	4 –27		10	91		35	29
	TW	4 –51		10	91		31	26
'Robut 33-1'× 'NC Ac 17090'	PY	–	5	–	–	46	–	–
	SP	9		1	20		1	2
	TW	11		1	20		1	2
'Robut 33-1'× 'PI 298115'	PY	1 –92	5	4	80	33	10	30
	SP	3		1	20		1	3
	TW	3 –58		3	60		8	24
'MK 374'× 'GAUG 1'	PY	0.4–12	7	4	57	21	4	19
	SP	0.3–20		3	42		4	19
	TW	3 –37		2	29		2	10

Cross	Character	r_1	S_2					
			Progeny			Plants		
			n	t	p	n	t	p
'Robut 33-1'× 'Chico'	PY	10– 45	8	7	88	57	21	37
	SP	5– 15		5	63		20	35
	TW	13– 38		7	88		37	65
'Robut 33-1'× 'NC Ac 17090'	SP	4– 37	9	3	33	59	4	7
	TW	3– 12		6	67		19	32
'Robut 33-1'× 'PI 298115'	PY	16– 68	10	9	90	53	26	49
	SP	3– 24		6	60		15	28
	TW	3– 95		7	70		18	34
'MK 374'× 'GAUG 1'	PY	26–164	8	6	75	37	9	24
	SP	6– 13		3	38		4	11
	TW	11– 39		7	88		17	46

n = total; t = frequency superior to F_1; p = 100 t/n; r_1 = range of improvement in progeny superior to F_1; PY = single plant pod yield; SP = shelling percentage; TW = 100-kernel weight synthetic area and specific leaf weight; post flowering: number of primary branches, number of secondary branches, photosynthetic area and specific leaf weight; and harvest: number of mature pods, weight of mature pods, number of mature kernels, weight of mature kernels or kernel yield, maturity index of pods, shelling percentage and weight of 100 kernels. In order to rank the individual performance of S_2 and F_2 of all four crosses together, the percent improvement of each S_2 and F_2 plant over the better parent was calculated for each character. Their values were used to set up a multiple regression index with the improvement in single plant kernel yield as the dependent and the rest as independent variables. The expected values of improvement in pod yield given by the index were ranked in ascending order to provide a ranked second generation distribution (RDIS). The RDIS was divided into equal parts to provide four strata: T_1 = top 25% of plants in second generation; T_2 = 26–50%; T_3 = 51–75% and T_4 = 76–100%. Plants falling in various strata were advanced to the third generation by selfing. The proportion of F_2 and S_2 plants from various crosses occurring in the strata T_1, T_2 and (T_3+T_4), their mean yield performance and their yield improvement in the third generation were used to evaluate the efficiency of the mating system in bringing about yield improvement.

Results

In general the frequency of plants occurring in the top two strata, T_1 and T_2, was consistently higher in the case of S_2 than F_2 (Table 1). The number of plants in T_2 was, however, larger for F_2 than S_2 in the cross, 'Robut 33-1'×'Chico' and equal in 'MK 374'×'GAUG 1'. Intermating could thus generate recombinants with higher yields than selfing. The frequency of such recombinants depended also on the potential of the parental genotypes involved in the cross.

The role of intermating in bringing about an improvement in yield was more apparent when the yield of S_2 and F_2 was compared to that of F_1 (Table 2). The range of improvement in plants superior to F_1 for single plant pod yield, shelling percentage and 100-kernel weight was consistently higher in S_2 than F_2. Progeny families outyielding F_1 performance were also more numerous when derived by intermating than by selfing. The results shed more light on the superiority of intermating as a technique for promoting yield improvement.

The superiority of S_2 over F_2 shown in their improvement over F_1 was apparent in the mean values of S_2 and F_2 for pod yield, shelling % and 100-kernel weight in each cross (Table 3). However, S_2 superiority was variable when the values of those yield components were compared at the stratum level.

The yield performance of families advanced to the third generation established the superiority of those derived earlier by intermating (Table 4). Whether the third generation performance was examined in the families derived from the top 25%, 26–50%, or 51–100% of plants from RDIS, the superiority of families advanced from S_2 was apparent in single plant and per

Table 3. Yield performance of F_2 and S_2 in various selection strata

Cross	Stratum	F_2			S_2		
		PY	SP	TW	PY	SP	TW
'Robut 33-1'×'Chico'	1	23.8	64.7	27.4	28.1	60.8	36.1
	2	15.8	56.8	26.6	18.3	58.5	32.8
	3	10.8	50.5	27.2	11.2	50.8	29.7
	4	4.7	43.9	20.4	6.3	35.7	21.6
	m	10.3	50.2	24.5	17.7	52.9	30.9
'Robut 33-1'×'NC Ac 17090'	1	25.8	53.3	31.6	28.6	67.9	38.1
	2	18.7	49.4	25.9	16.5	61.0	32.0
	3	11.9	44.3	26.3	11.0	48.6	25.9
	4	5.8	38.9	24.9	5.9	41.2	23.0
	m	13.8	45.3	26.4	17.2	57.3	31.1
'Robut 33-1'×'PI 298115'	1	35.9	59.9	32.1	27.5	67.0	34.1
	2	19.8	48.3	29.3	16.6	61.5	33.9
	3	8.9	52.9	31.5	8.9	52.9	27.4
	4	4.5	50.2	27.0	6.1	49.9	27.1
	m	12.9	52.2	29.5	17.7	60.6	32.5
'MK 374'×'GAUG 1'	1	24.2	53.8	25.3	20.8	48.7	31.6
	2	9.9	52.3	28.1	10.0	46.3	28.0
	3	8.7	35.7	18.6	6.7	42.6	27.9
	4	2.5	45.2	19.6	4.5	31.4	19.3
	m	9.1	45.4	22.2	11.3	43.0	27.5

PY = single plant pod yield; SP = shelling percent; TW = 100-kernel weight; m = mean

Table 4. Yield improvement recorded in third generation

Characters	'Robut 33-1'× 'Chico'			'Robut 33-1'× 'NC Ac 17090'			'Robut 33-1'× 'PI 298115'		'MK 374'× 'GAUG 1'
	T_1	T_2	T_3^*	T_1	T_2	T_3^*	T_1	T_3^*	T_1
F3S									
PY	9.0	12.6	10.7	12.0	7.1	11.5	14.4	8.1	6.6
SP	70.1	62.4	64.9	59.3	54.3	66.4	61.0	59.0	52.9
TW	38.4	40.6	34.0	40.6	39.8	32.0	40.7	34.6	34.1
HY	1,507	1,992	1,820	2,382	1,410	2,103	2,192	1,797	1,338
F3F									
PY	5.0	9.5	5.2	6.2	4.7	9.5	12.9	4.2	4.1
SP	63.3	53.5	48.9	68.5	58.6	56.3	60.2	62.5	60.9
TW	26.3	26.7	23.4	38.3	37.8	28.2	35.6	27.3	39.3
HY	1,050	758	622	1,413	1,110	1,867	1,737	793	690
R									
PY	79	33	107	93	53	21	12	93	62
SP	11	17	33	6	−7	18	1	−6	−13
TW	46	52	45	−13	5	13	5	27	−13
HY	43	163	193	69	27	13	26	126	94

F3S = third generation of S_2 by selfing; F3F = third generation of F_2 by selfing; R = % improvement of F3S over F3F; T_1 = progeny descending from top 25% of F_2 or S_2; T_2 = progeny descending from top 26 to 50% of F_2 or S_2; $T_3^* = T_3 + T_4$ = progeny descending from top 51–100% of F_2 or S_2; PY = single plant pod yield; SP = shelling %; TW = 100-kernel weight; HY = pod yield kg/ha (estimated on the yield of 4 rows in an area of 6 sq.m.)

Table 5. Mean and variance for single plant pod yield in normal and irradiated parents

Parent	Normal			Irradiated		
	m	sd	cv	m	sd	cv
'Robut 33-1'	42.9	10.68	25	42.1	13.57	32
'PI 298115'	37.8	9.95	26	27.1	16.59	61
'NC Ac 17090'	44.0	8.47	19	33.6	11.69	35
'MK 374'	36.9	18.62	51	36.4	24.94	68
Overall	40.4	12.47	31	34.8	17.63	51

Values based on 10 plants; m = mean; sd = standard deviation; cv = coefficient of variation

hectare pod yield in each cross. The results were consistent for shelling % and 100-kernel weight, in general; but, in three crosses marginal superiority of families advanced from F_2 to the extent of 6 to 13% was observed. The results could be attributed to the potential of parental genotypes involved in F_1.

Discussion

It is recognised that intermating in segregating populations promotes recombination and breaks undesirable linkages (Hanson 1959; Miller and Rawlings 1967; Yonezawa 1983). At the same time, reports vary on when to practise it. While, in general, intermating has been advocated in early segregating generations (Comstock and Robinson 1948), delaying it until later generations has also been found to be advantageous (Stam 1977).

In this study, intermating was done in the F_1 generation raised from irradiated F_0 seeds. One generation of intermating could record subtantial yield advantages in the third generation.

Logically the F_1 generation is supposed to be genetically uniform, usually comprised of heterozygotes. However, it is not uncommon to discover genetic segregation in parental genotypes in groundnut. This is attributed to the possibilities of tetrasomic inheritance. This point can be debated; however, parental variability for pod yield was noted (Table 5). The coefficients of variation could be to an extent inflated by the small sample size of 10 plants. The variation was, however, enlarged by irradiation in all the parents. Mean and coefficient of variation were computed for pod yield in F_1 and F_2 raised from normal and irradiated F_0 seeds (Table 6). The reduction in mean on irradiation was followed by a relatively lower reduction in variance and hence by higher coefficients of variation. This trend was consistent both in F_1 and F_2. The results showed the possibility of irradiation altering a number of genotypes in the effects of a few loci. As a result of production of some inferior genotypes, the mean value was depressed under irradiation, but intermating promoted mating among high

Table 6. Mean and variance for single plant pod yield in F_1 and F_2 generations raised from irradiated and normal F_0 seeds

Cross	F_1							F_2						
	Normal			Irradiated			*n*	Normal			Irradiated			*n*
	m	sd	cv	m	sd	cv		m	sd	cv	m	sd	cv	
'Robut 33-1' × 'Chico'	36.1	13.50	37	20.7	9.91	48	10	14.8	8.93	60	10.0	6.02	60	160
'MK 374' × 'Chico'	22.1	19.93	90	20.2	15.33	76	12	12.5	8.13	65	8.3	6.39	77	129
'MK 374' × 'GAUG 1'	31.9	20.78	65	15.1	14.46	96	12	15.1	15.88	105	8.6	7.11	83	28
Overall	29.7	22.77	77	18.5	14.07	76	34	13.9	9.48	68	9.05	6.31	70	317

n = number of plants; m = mean; sd = standard deviation; cv = coefficient of variation

and low genotypes generating superior genotypes (see Langham 1961) and hence yield improvement in S_2 and its later generation. When possible, it would be fruitful to get an idea of the frequency of low genotypes in the field, though approximate. This would help in a judicious avoidance of a large number of low × low matings. In this respect, the utility of seedling phase characters in identifying final high and low status has been reported earlier (Arunachalam et al. 1980). This fact gains significance when we consider that the sample sizes used to generate F_2 and S_2 were small. Under such conditions, common in groundnut breeding, losing heterozygosity by allowing selfing, as generally happens in pedigree breeding, can be detrimental. The results of our experiments suggest that it would be advantageous to practise intermating even in early generations provided sufficient genetic variability is ensured. A few cycles of intermating could then recombine the genes from the upper and lower ends of the genotypic distribution in each generation to produce adequate potential variability for initiating selection.

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