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Variation in reproductive efficiency and flowering behaviour of cultivated groundnut

R.K. Mathur[1]*, P.K. Ghosh[2] and P. Manivel[3]

National Research Centre for Groundnut, ICAR, PO. Box-5, Ivnagar Road, JUNAGADH (GUJARAT) INDIA

ABSTRACT

The study was undertaken to understand the reproductive efficiency and flowering behaviour of different forms of cultivated groundnut, and to know the extent and scope of conversion of flowers into pegs, pods and kernels. The genotypes included in the experiment were taken two from each habit group. VL genotypes possessed high reproductive efficiency followed by SP in converting maximum flowers into pods. The correlation study indicated that flowers produced up to 50 DAS had good association with mature pod number and should be given due attention to select high yielding genotype with more proportion of mature pods. Relative humidity recorded at 2 PM had impact on flower production. Maximum temperature was negatively correlated with flowers for all the genotypes of VL and SP but it was positive with Virginia types except Somnath. Association of rainfall with flowers was mostly negative. The stepwise regression analysis revealed importance of the low temperature on the flower production in both rainy and summer seasons. The Virginia runner genotypes were sensitive to rainfall. In summer season no significant effect of relative humidity on flower production was observed. Gangapuri was found sensitive to duration of sunshine hours. Impact of weather parameters on flower production was not found in the both Valencia genotypes and Somnath, but minimum temperature had significant effect in other genotypes.

Key words: Groundnut, Reproductive efficiency, Flowering pattern, Multiple regression, Weather parameters.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is an autogamous and indeterminate legume crop. There is generally a big gap between the number of flowers produced and the number of mature pods formed from them (reproductive efficiency). The reproductive efficiency, defined as the percentage of viable reproductive tissues (Pattee and Young, 1992), in groundnut is assessed by flowers, pegs, mature pods, immature pods, sound kernels and unsound kernels (Coffelt *et al*., 1989). Less than 10 per cent of the flowers produced develop into mature pods (Othman 1979; Lim *et al*., 1980). There are four varietal forms of groundnut cultivated in India *viz*., Valencia (ssp. *fastigiata* var. *fastigiata*), Spanish bunch (ssp. *fastigiata* var. *vulgaris*), and Virginia bunch and Virginia runner (ssp. *hypogaea* var. *hypogaea*). Maturity differences between groundnut genotypes belonging to different varietal forms have been observed (Chunilal *et al*., 1997; Ghosh *et al*., 1997). The systematic study on flowering behaviour and reproductive efficiency of genotypes belonging to different varietal forms in groundnut is meagre. With this view, the present investigation was undertaken (i) to understand the reproductive efficiency and flowering behaviour of different forms of cultivated groundnut, and (ii) to know the extent and scope of conversion of flowers into pegs, pods and kernels.

MATERIALS AND METHODS

The experimental material included eight genotypes belonging to four-habit groups of groundnut *viz*., Gangapuri and MH 2 (Valencia type), JL 24 and GG 2 (Spanish bunch type), Kadiri 3 and BG 1 (Virginia bunch type) and Somnath and GAUG 10 (Virginia runner type). The experiment was conducted in completely randomized design with three replications during two rainy and two post-rainy seasons at the National Research Centre for Groundnut, Junagadh, Gujarat. In each replication three pots were maintained. Five plants were maintained in each pot keeping Optimum plant-to-plant distances. Hoagland's nutrient solution (Hewitt, 1966) was applied to each pot at 15 days' interval starting from the 10th day and was continued up to 40 DAS. The number of flowers opened between 0900 to 0930 hours each morning was recorded on the main axis, primary and secondary branches separately from date of initiation of flowers till 80 days after emergence (DAE). The data on total number of flowers produced by each genotype were used to calculate the days taken to complete 25%, 50% and 75% flowering. Contributions of main axis, primary and secondary branches to the total flowers and pods were calculated and expressed in percentage. Mature pods were separated from immature pods, which were identified by their shriveled seeds. The plants and pods were oven dried at 65±5°C for 48 hours and their weights were recorded in grams. The pegs that had penetrated the soil surface, turned horizontally and elongated to at least 1cm were classified as immature pods. Hanging pegs were those that could not be classified as immature pods. The total numbers of mature pods, total pods per plant, total pegs per plant and pod yield per plant were counted, weighed and used to compute the reproductive efficiency (RE) indices using the following formulae outlined by Coffelt *et al*., (1989).

$$RE\ 1 = \frac{\text{Pod yield}}{\text{Total biomass}} \times 100$$

* Author for corrospondence. Present Address :

[1] NRC for Oil Palm, Pedavegi (A.P.)

[2] Indian Institute for Soil Science, Bhopal (M.P.)

[3] Central Potato Research Institute, Shimla (H.P.)

$$RE\ 2 = \frac{\text{Total pods + Total pegs}}{\text{Total flowers}} \times 100$$

$$RE\ 3 = \frac{\text{Total pods}}{\text{Total flowers}} \times 100$$

$$RE\ 4 = \frac{\text{Total pods}}{\text{Total pegs}} \times 100$$

$$RE\ 5 = \frac{\text{Mature pods}}{\text{Total pods}} \times 100$$

$$RE\ 6 = \frac{\text{Mature pods}}{\text{Total flowers}} \times 100$$

Being indeterminate in growth habit, the groundnut genotypes do differ with regard to the optimum time of maturity. The harvesting of plants was done at 1700 growing degree days (GDD) in rainy and 1900 growing degree days in post-rainy seasons. This might have introduced the possibility of biasness in the real evaluation of the genotypes. To overcome this the proportion of total pegs to the total flowers (RE 2) and total pods to total flowers (RE 3) were estimated. The correlation and regression analyses were done following Gomez and Gomez (1976).

RESULTS AND DISCUSSION

Reproductive Efficiency :

The reproductive efficiency was estimated as The six reproductive efficiency indices estimated for different genotypes over two rainy and two summer seasons are presented in Table 1.

Rainy season :

The harvest index (RE 1) was recorded highest in Spanish (SP) types followed by Valencia (VL). The genotypes GG 2 (SP) and MH 2 (VL) recorded the highest harvest index (65.7 and 65.3%, respectively). Thus, it appeared that these types were efficient in translocating the maximum photosynthates into the pods. The total pegs to total flower ratio (RE 2) was high in VL and Virginia runner (VR) groups. The estimates of other four indices *viz*., total pods to total flower ratio (RE 3), total pods to total peg ratio (RE 4), mature pods to total pod ratio (RE 5) and mature pods to total flower ratio (RE 6), were the highest in VL types and the lowest in VR types. Thus in rainy season, unlike the VR types VL types are reproductively most efficient in converting maximum number of flowers into mature pods with least proportion of hanging pegs and immature pods at the harvest.

Summer season :

The means of all the indices except RE 4 and RE 6 were higher in summer than rainy season. The total pegs to total flower ratio (RE 2) was high in VL and VR groups and was unaffected by the season. The VL and SP types

Table 1: Reproductive efficiency indices (%) of eight genotypes belonging to four varietal forms of groundnut.

Habit	Genotypes	RE 1		RE 2		RE 3		RE 4		RE 5		RE 6	
Group		R	S	R	S	R	S	R	S	R	S	R	S
Valencia	Gangapuri	45.9	31.0	77.3	42.1	34.1	25.7	44.5	61.5	82.0	58.6	27.8	15.0
	MH 2	65.3	38.0	64.0	57.4	36.3	37.6	56.3	66.2	91.0	56.2	33.0	21.1
	Mean	55.6	34.5	70.7	49.8	35.2	31.7	50.4	63.9	86.5	57.4	30.4	18.1
Spanish	JL 24	54.8	34.0	48.6	47.5	26.4	31.0	54.9	63.8	76.1	65.1	19.2	20.1
	GG 2	65.7	36.5	40.3	39.1	21.5	27.7	25.6	59.4	79.6	84.9	16.6	21.8
	Mean	60.3	35.8	44.5	43.3	24.0	29.9	40.3	61.6	77.9	75.0	17.9	21.0
Virginia	BG 1	47.8	37.0	39.4	32.9	15.5	16.2	39.5	56.1	67.4	50.4	10.5	9.2
Bunch	Kadiri 3	34.5	28.0	62.4	44.7	25.8	21.6	41.4	50.5	68.9	45.8	17.9	10.3
	Mean	41.2	32.5	50.9	38.8	20.7	18.9	40.0	53.3	68.2	48.1	14.2	9.8
Virginia	Somnath	46.9	39.1	77.4	46.9	19.4	24.2	25.6	53.3	52.6	61.2	10.2	14.8
Runner	GAUG 10	36.1	24.3	66.3	79.7	20.2	35.2	30.1	44.6	69.8	41.5	13.9	14.7
	Mean	41.5	31.7	71.9	63.3	19.6	29.7	27.9	49.0	61.2	51.4	12.1	14.8
	S.E. (±)	4.2	1.9	5.4	5.1	2.6	2.5	4.3	2.6	4.1	4.8	2.9	1.7
	Heritability	89.1	90.2	80.3	83.8	62.9	70.5	67.9	72.2	88.5	93.4	86.2	89.4
	Genetic advance	21.1	24.2	13.3	16.5	9.3	12.8	20.7	26.5	30.0	36.4	21.0	28.4
	GCV (%)	21.8	26.1	38.7	42.5	22.9	33.9	20.6	28.0	32.2	38.4	36.3	39.2
	PCV (%)	23.1	32.5	43.2	46.2	28.9	29.5	24.9	31.2	36.3	44.6	27.4	45.2

Rainy; S= Summer; GCV= Genetic Coefficient of variation; PCV= Phenotypic Coefficient of variation

were found to be the reproductively efficient in summer also as the estimates of all the six RE indices were high (Table 1). In this season the Virginia bunch (VB) types were found reproductively least efficient as the mature pod to total flower ratio (RE 6) was least in this group thus, reflecting the more proportion of hanging and immature pods at the harvest. Among Virginia types VR performed better than VB though it is not significant. Heritability estimates of all these RE indices were computed and found high, except for RE 3 and RE 4 (Table 3). Genotypic coefficient of variation (GCV) estimate indicated high genetic variability available for the RE 2.

Table 2: Total flowers, flower initiation and contribution of branches to flowers and pods produced in four varietal forms of groundnut.

Habit group	Genotypes	Total flowers		Days to flower initiation		Per cent flower produced on			Per cent pods produced on		
		R	S	R	S	MA	PB	SB	MA	PB	SB
Valencia	Gangapuri	18.2	23.1	23.5	33.0	27.5	72.5	0.0	6.9	93.1	0.0
	MH 2	25.1	12.0	24.0	33.5	24.7	75.3	0.0	10.0	90	0.0
Spanish	JL 24	47.6	25.6	23.0	33.5	16.5	83.5	0.0	7.2	92.8	0.0
	GG 2	61.6	37.4	24.0	33.0	27.6	72.4	0.0	3.6	96.4	0.0
Virginia	BG 1	56.5	48.9	30.0	32.0	12.9	83.1	0.0	5.4	92.6	2.0
bunch	Kadiri 3	59.3	57.0	28.5	41.2	0.0	100	0.0	0.0	100	0.0
Virginia	Somnath	51.3	35.4	27.0	39.7	14.2	84.3	1.5	9.0	90.5	0.5
runner	GAUG 10	51.7	80.0	30.0	34.2	0.0	96.3	3.2	0.0	96	4.0

R= Rainy, S= Summer, MA= Main axis, PB= Primary branch, and SB= Secondary branch

The seasonal effects were not noticed on flowering behaviour of VB and VR types. Variation in flowering pattern between VB and VR types was observed. In VR types, the flower production was continuous whereas in VB types peak flowering up to 60 DAS and it was ceased at 70-75 DAS. In summer season the flowering in JL 24 was erratic and occasional flower production continued up to 80 DAS.

Table 3 : Association of flowers produced and weather parameters in rainy and summer seasons.

Genotype	Relative Humidity		Maximum temperature		Minimum temperature		Growing Degree Days		Vapour Pressure Deficit		Sunshine hours		Rainfall
	R	S	R	S	R	S	R	S	R	S	R	S	R
Gangapuri	0.03	-0.07	-0.27	-0.19	0.46**	0.02	-0.69**	-0.57**	-0.41**	-0.54**	-0.20	0.33*	-0.10
MH 2	0.09	-0.00	-0.34*	-0.00	0.15	0.13	-0.43**	-0.36**	-0.36**	-0.49**	-0.11	0.16	-0.31*
JL 24	0.02	-0.13	-0.34*	0.11	0.45**	0.16	-0.66**	-0.44**	-0.46**	-0.56**	-0.26*	-0.10	-0.17
GG 2	0.10	-0.14	-0.29	0.19	0.38**	0.33*	-0.61**	-0.55**	-0.40**	-0.43**	-0.25*	0.19	-0.09
BG 1	0.05	0.06	-0.33*	0.10	0.33*	0.35*	-0.57**	-0.52**	-0.42**	-0.35*	-0.21	0.19	-0.21
Kadiri 3	-0.05	0.02	-0.06	0.19	-0.48**	0.39**	0.35*	-0.21	0.10	0.24	0.30*	-0.03	0.00
Somnath	-0.40**	-0.12	0.52**	-0.14	-0.50**	-0.16	0.82**	0.55**	0.64**	0.71**	0.52**	0.20	-0.16
GAUG 10	0.06	-0.04	-0.03	0.27	-0.53**	0.43**	0.46**	0.64**	0.14	0.23	0.25	0.06	0.09

FLOWERING BEHAVIOUR

Flower number and initiation:

VL and SP types were earliest in flowering while the Virginia types were late. In both the seasons the numbers of flowers produced in VL types were lowest (Table 2). In Virginia types the range of total flowers per plant was narrow in rainy season (51.3 to 59.3) whereas it was wide in summer season (35.4 to 80.0). The differences were observed for behaviour of the genotypes in producing the flowers during the crop period. VL and SP types had shown distinct variation in flowering in both rainy and summer seasons. In both the seasons VL types completed total flowering within 15-18 days after flower initiation. Moreover, the flower production ceased at 45-50 DAS. But in summer season the mean number of flowers of MH 2 was higher than that of Gangapuri. In rainy season the SP types continued flowering period was observed between 40-45 DAS, thereafter the rate of flower production declined.

Contribution of branches to flowers and pods:

In VL and SP genotypes, main axis contributed about the 1/4th of the total flower produced (Table 2). The remaining flowers (3/4th) were produced on primary branches. In the VB and VR genotypes the main axis contributed less than 20%, primary branches produced about 80-100% and secondary branches produced only 6% of the total flowers. The similar trend was also observed in case of contribution of different branches to pod produced

(Table 2). Interestingly, the main axis flowering was noticed in one VB genotype (BG 1) and one VR genotype (Somnath), which is otherwise peculiarity of the VL and SP types (Gregory *et al*., 1951).

Thus our results showed that VL genotypes possessed high reproductive efficiency in converting maximum flowers into pods followed by SP. There is a wide scope for converting about 32 and 39% immature pods into mature pods in VB and VR genotypes, respectively possibly through soil and agronomic manipulations. A high yielding genotype should produce more number of pods per plant through higher number of pegs (flower to peg ratio) and higher percentage of pegs forming mature pods (peg to pod ratio). In this study, among the genotypes, MH 2 was the most reproductively efficient genotype followed by GG 2 when various RE indices were considered together. Information obtained in this study may be useful for the breeders for incorporating the reproductively efficient lines in their breeding programmes aimed at developing high yielding reproductively efficient cultivars. Pattee and Stalker (1991) reported use of VL and SP genotypes as paternal parent for achieving high RE for wild crosses of *Arachis*.

CORRELATION AND REGRESSION ANALYSIS

The correlation coefficients between the cumulative flower count at different durations and the number of mature pods, immature pods and hanging pegs were studied (Table 4). The association of mature/immature pods with flowers produced up to 30 DAS (initial flowering) was non significant. The magnitude of positive association with number of mature pods was high up to 50 DAS and thereafter it declined; the same with immature pods and hanging pegs was negative or almost zero up to 50 and 55 DAS, respectively, thereafter the association was recorded positive.

Flower number and weather parameters :
***Rainy season*:**

The effect of weather parameters (Table 4) on flower production was studied. Relative humidity recorded at 2 PM had impact on flower production. The association was significant only for Gangapuri (r= 0.31), Kadiri 3 (r= -0.39) and GAUG 10 (r= -0.45) genotypes. However, the relative humidity at 8 AM did not show any impact on the flower production. Valencia and Spanish types had negative association of flower production with maximum temperature; it was positive with Virginia types except Somnath. The reverse trend was observed for minimum temperature. Association of rainfall with flowers was mostly negative but non-significant except MH 2. The correlation between sunshine hours and flowers was negative and mostly non significant except Somnath (r= -0.34). The stepwise

Table 4 : Correlation coefficients ('r') between number of flowers with number of mature pods, immature pods and hanging pegs in rainy and post rainy seasons in groundnut.

Rainy season				Post rainy season			
GDD	Mature pods	Immature pods	Hanging pegs	GDD	Mature pods	Immature pods	Hanging pegs
425	-0.59	-0.19	0.09	464	-0.20	0.13	0.21
478	-0.44	-0.17	0.07	519	-0.27	0.01	0.17
532	-0.35	-0.25	-0.04	573	0.09	0.24	0.51
587	-0.40	-0.27	0.17	627	0.25	0.43	0.59
641	-0.43	-0.28	0.16	680	0.22	0.32	0.58
695	0.30	-0.15	-0.12	734	0.43	0.33	0.71
750	0.56	0.54	-0.01	784	0.59	0.47	0.80*
803	0.38	0.81*	0.24	825	0.63	0.45	0.85**
854	0.37	0.82*	0.32	879	0.72*	0.47	0.85**
906	0.40	0.84**	0.40	933	0.75*	0.43	0.82*
959	0.32	0.86**	0.39	983	0.80*	0.47	0.80*
1013	0.10	0.96**	0.55	1034	0.80*	0.54	0.88**
1068	0.09	0.95**	0.57	1084	0.96**	0.88**	0.95**
1120	0.09	0.92**	0.65	1135	0.96**	0.73*	0.89**
1173	0.02	0.81*	0.75*	1180	0.95**	0.74*	0.93**
1230	0.10	0.61	0.64	1229	0.94**	0.70*	0.91**
1286	0.03	0.42	0.64	1279	0.84**	0.47	0.63
1344	0.18	0.36	0.64	1323	0.88**	0.54	0.62
1402	-0.11	0.30	0.89**	1369	0.91**	0.72*	0.61
1459	-0.10	0.25	0.83**	1416	0.65	0.78*	0.36

regression analysis revealed importance of low temperature on flower production. Interestingly, two Virginia runner genotypes- GAUG 10 and BG 1 had shown significant impact of rainfall in positive and negative directions whereas the low relative humidity was also found to affect flowering more number of immature pods. Relative humidity had impact on flower production. Maximum temperature was negatively correlated with flowers for all the genotypes of VL and SP but it was positive with Virginia types except Somnath. Association of rainfall with flowers was mostly

Table 5 : Stepwise regression analysis involving number of flowers and the weather parameters as the independent variables in groundnut.

Genotypes	Seasons	Regression Equations	R^2 values	
			R	S
Gangapuri	Rainy	$Y= -51.95 - 0.80X_3 + 3.36X_4$	0.33	0.35
	Summer	$Y= -0.29 - 0.40X_5$	0.23	0.11
MH 2	Rainy	$Y= 48.47 - 0.19X_6 - 1.26X_3$	0.45	0.21
	Summer	NS	0.06	---
JL 24	Rainy	$Y= -116.81 +5.09X_4$	0.36	0.23
	Summer	NS	0.09	---
GG 2	Rainy	$Y= -154.85 + 6.79X_4$	0.26	0.22
	Summer	$Y= -10.71 +0.88X_4$	0.17	0.11
BG 1	Rainy	$Y= 265.45 - 0.34X_6 - 9.93X_4$	0.40	0.23
	Summer	$Y= -19.50 + 1.27X_4$	0.20	0.18
Kadiri 3	Rainy	$102.70 - 0.17X_2 - 3.12X_4$	0.63	0.31
	Summer	$Y= -21.44 + 1.43X_4$	0.16	0.15
Somnath	Rainy	$Y= -163.63 +7.32X_4$	0.26	0.24
	Summer	NS	0.14	---
GAUG 10	Rainy	$Y= 32.81 + 0.13X_6 + 0.32X_2$	0.72	0.32
	Summer	$Y= -24.03 + 2.13X_4$	0.20	0.13

X_1= Relative Humidity at 8 AM (%); X_2= Relative Humidity at 2 PM (%); X_3 Maximum temperature (°C); X_4= Minimum temperature (°C); X_5= Sunshine hours; and X_6= rainfall (cm) NS= non significant

in Kadiri 3. The range of R^2 value was from 0.26 - 0.72. The weather parameters had more effect on the long duration Virginia runner genotypes than the others.

***Summer season*:**

Relative humidity at 8 AM and 2 PM did not have any effect (Table 4). The association of number of flowers and sunshine hours was positive and significant for Gangapuri only; correlation with minimum temperature was positive and significant only for GG 2, Kadiri 3, GAUG 10 and BG 1, but the effect of maximum temperature in summer was negligible for all the types. The stepwise regression analysis revealed no significant effect of relative humidity on flower production. Gangapuri was found sensitive to duration of sunshine hours. Effect of weather parameters on flower production was not found in Valencia types and Somnath, but minimum temperature had significant effect in other genotypes.

The R^2 values ranged from 0.26 to 0.72 in rainy and 0.00 to 0.23 in summer seasons. The estimates of R^2 were higher in rainy season than in summer, thus, indicating more roles of weather parameters in rainy seasons on the amount of flowers produced than in post rainy season.

The flowers produced between 50-65 DAE result in negative. Gangapuri was found sensitive to duration of sunshine hours. Impact of weather parameters on flower production was not found in the both Valencia genotypes and Somnath, but minimum temperature had significant effect in other genotypes.

In nut shell, Valencia genotypes possessed high reproductive efficiency followed by Spanish types in converting maximum flowers into pods. MH 2 was reproductively most efficient genotype followed by GG 2. Flowers produced up to 50 DAE had good association with mature pod number, which could be used as an indicator for selecting high yielders. The stepwise regression analysis revealed importance of low temperature on flower production in both rainy and summer seasons. The Virginia runner types were sensitive to rainfall. In summer season no significant effect of relative humidity on flower production was observed.

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