A Note on the Earliness of Offspring from Crosses Among Five Short Growth-Duration Peanut Lines[1]

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ABSTRACT

Short growing seasons, such as those that occur in semi-arid regions of West Africa, prevent peanut (*Arachis hypogaea* L.) from maturing properly. Immature fruit lowers peanut quality and yield, and enhances growth of toxin-producing molds during storage. Germplasm with expressed accelerated development for use as parents in developing early maturing (75 day) cultivars suited for production in those regions is limited. Information on the genetic variability for earliness among the very early maturing candidate parental lines is lacking. Five erect, early maturing peanut lines of diverse origin were crossed in diallel; and parent, F_1, and F_2 generation progeny from plantings on four dates were compared. Measures were made on a plant basis for the number of days from planting to emergence (DEMR), number of days to first (DONE), fifth (DFIV), tenth (DTEN), fifteenth (DFIFT), twentieth (DTWEN), and twenty-fifth (DTW5) flower; and, following early digging, for number of full-size pods (FULL), number of mature pods (NUMP), and percent mature pods (%MP). F_2 segregates that emerged and flowered earlier than parental and F_1 plants were noted. Coefficients of correlation for DEMR and flowers DONE to DTW5 with FULL, NUMP, and %MP were negative; the association being stronger with FULL and NUMP than with %MP. R values were highest for DTW5 with FULL and NUMP, and decreased progressively with lower flower numbers (longer time intervals between measures) which indicated that the developmental rate was not consistent among genotypes. Mean broad sense heritability estimates for the traits examined ranged from 36 to 45%. H estimates for specific reproductive stages on individual crosses ranged from 4 to 65%, but for no cross were the H values consistently high for all measures. Both general and specific combining abilities were insignificant. The frequency of F_2 plants with FULL and NUMP extending the range of their parents was low. Opportunity for selection of recombinants that would produce large numbers of full-size and mature pods faster than that of the parental lines might be possible in some of the crosses. The extent of potential decrease in growth duration could not be estimated from this study.

Key Words: Groundnut, growth duration, *Arachis hypogaea*, early generation selection.

Immature pods at harvest lower peanut (*Arachis hypogaea* L.) quality and yield. The rainy seasons in semi-arid regions of Africa are short, and current cultivars often fail to mature. During short seasons the ability of a variety to mature a reasonable quantity of fruit often becomes more important than high yields.

55-437, with a growth duration of approximately 90 days in Senegal (6), is perhaps the most widely grown peanut cultivar in the dry, short rainy-season peanut-growing region just South of the Sahara. Short growing seasons, though characteristic of the area, have become increasingly more frequent and extreme during the past 15 years. Peanut is an important cultigen for the area, both for cash and food crop purposes. 55-437, and other cultivars of similar growth duration, often fail to mature. Earlier-maturing (75-day) varieties adapted to those environments are needed.

Critical components of any successful plant breeding program are 1) the selection of parents with genetic variation for the trait(s) of importance, and 2) an effective selection method. Reported variation for 75-day growth duration, equivalent to approximately 90-day in most of the U.S., germplasm is scarce. Chico (3) is among those germplasms, and is probably the most widely used source of earliness. However, no cultivar, agronomically acceptable for commercial cultivation, with growth duration equal to Chico has been reported.

Early classification of plants for the trait under consideration increases the efficiency of a breeding program. Various methods to estimate maturity have been published (9, 11, 12, 14, 20, 21, 26, 28), but if enforcement is to be applied on large populations in early filial generations, classification must be non-destructive and rapid. The meeting of these requirements restricts the options for ascertaining relative growth duration in a breeding program for early generation population assessment. The approaches to these determinations have involved evaluations of elapsed time from planting to emergence, to various stages of flowering, or varied proportions of mature pods. Bailey and Bear (2) compared lines on the basis of days from planting to varied numbers of flowers per plant, seed maturation, and peg deterioration, and reported genetic differences among maturity classes of 50 days. Success in predicting relative maturity based on flowering was progressive as flower numbers per plant increased. Michaels examined days to emergence as a selection criterion for early development without success (17). Hassan and Srivastava reported that early-maturing cultivars begin flowering two or three days sooner than late-maturing cultivars, but they were unable to positively relate other flowering characteristics to pod maturation (11). Khalfoui found strong phenotypic correlations between precocity components and percentage of mature pods at 90 days, the strongest correlation being with days from planting to 50 flowers (15). He later concluded that days to emergence and start of flowering do not provide a dependable role in selection for early maturation. (16)

Breeding for rapid plant development has met with mixed success and has been especially difficult in shortening the growth cycle below that of traditional spanish cultivars (4, 7, 17, 18, 23, 27). Shortened growth duration, without associated acceptable agronomic and quality characteristics, is of little commercial benefit. Furthermore, research has produced varied results or led to varied interpretations on the nature of inheritance, including mode of gene action, number of genetic factors and effects of the cytoplasm. Slow

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(late) maturation dominance, early maturation dominance, and mixed results have been reported, and from one to five factors and modifiers have been proposed (8, 13, 16, 18, 19, 25, 27). A good synopsis of the literature concerning inheritance on growth cycle length was provided by Khalfoui (16).

Supplemental to the use of Chico as a parent for use in breeding for extreme earliness might be the use of other germplasms of extreme short growth-duration such as TxAG-1 and TxAG-2 (24). If factors conditioning rapid development vary among the early maturing germplasms, the growth duration could conceivably be shortened by recombination of those factors into a common genotype for culture or use as a parent.

This study was conducted to ascertain if genetic factors for earliness differ among five early-maturing germplasm lines of diverse origin, to estimate the heritability of factors producing differential earliness among the lines, and to determine if new recombinants for use as germplasm or cultivars could be developed. Both flowering and fruiting characteristics were examined to aid assignment of plants into maturity groups.

Materials and Methods

Vegetal Material

Five early maturing peanut lines (Chico, 55-437, TxAG-1, TxAG-2, and Tx851856) were crossed in complete diallel. All five germplasms have erect growth, and the first four have spanish pods. The pods of Tx851856 are larger and could be classified as runner. The lines are of diverse origin - Chico from Russia (3); 55-437 from Hungary (6); TxAG-1 and TxAG-2 from Texas, derived by mutation (19); and Tx851856 from Southeast Asia. Sixteen parent, 30 F_1, and 290 F_2 seeds of each parental combination, except for TxAG-1/TxAG-2 for which F_2 seeds were limited, were planted on a loamy siliceous thermic grossarenic paleustalf sandy loam soil west of Bryan, Texas. Plantings were made in a completely randomized design on each of four dates; thus, dates (replications over time) were blocks for analysis as a randomized complete block design. Seeds were spaced 40 cm within rows 91 cm apart. The planting dates were May 19, May 22, June 8, and June 26. Intervals between plantings were to 1) facilitate data collection and 2) reduce confounding effects that might occur from testing in a single environment. The late June 26 planting was a replant because of poor stands which resulted from excessive rain following a May 26 planting. A proportional number of seed from each population (parent, F_1, and F_2 from each cross and reciprocal) were planted on each date for a total of 820 seed per planting. Cultural practices, including chemical control of weeds, diseases, and insects, were consistent with recommended practices.

Traits Measured

Daily record of emergence and appearance of flowers one through 25 was made for each plant. For the first planting, all entries were hand-harvested 90 days after planting; for all subsequent plantings, entries were hand-pulled 90 days after 50% or more of the plants emerged. Plants within a cross were identified, bundled, and transported to the laboratory where the pods were removed by hand. Relative maturity was determined on a plant basis using freshly harvested pods classified as follows: pegs with ovaries greater than two times the diameter of the peg, fleshy pods (torpedo shape and larger), reticulated pods, one-seed pods, and full-size two-seed pods. After the pods were air-dried, the full-size two-seed pods were hand-shelled and subdivided as fully mature (based on internal pericarp color), intermediate, and shrivelled. Seeds from mature pods were counted for each plant and weighed.

Statistical and Genetic Analyses

Statistical analyses

Data were analyzed using the general linear model procedures to estimate population and generation means and variances. Homogeneity of variances among replications were tested by Bartlett's formula (5). Coefficients of correlation between traits were computed on an individual and a population-within-harvest date basis using SAS procedures (22).

Genetic analyses

Broad-sense heritabilities were calculated using F_2, F_1 and parent variances as described by Allard (1). Total genetic variance was computed as the difference between F_2 variance and V_E on an individual cross basis. Parent and F_1 variances were used to estimate V_E. The combining abilities of the parents were examined by use of Griffing's method 1 model 1 (10).

Results

Rain and cool night time temperatures (20 C) followed the first two plantings, and a prolonged wet period when the soil was near saturation followed the third planting. Thus, emergence in the first three plantings was slower than that from the fourth planting when conditions for emergence were near ideal.

The average number of days to emergence (DEMR) ranged from 5.9 days for date four to 19.1 for date three; however, the average DEMR was similar for the five parents (Table 1). Chico was the first parental line to produce five flowers per plant, but the rates of flowering were not equal and by the expansion of the fifteenth flower (DFIFT) all five parent lines were as advanced as Chico.

Table 1. Days from planting to emergence (DEMR), and flower numbers one (DONE) to twenty-five (DTW5), number of full-size (FULL) and mature (NUMP) pods, and percentage mature pods (%MP) for five parental lines grown near Bryan, TX, 1987.+

	Chico	55-437	TxAG-1	TxAG-2	Tx851856
DEMR	11a*	10a	11a	11a	11a
DONE	34b	35ab	39a	38ab	36ab
DFIVE	38b	42a	44a	44a	45a
DTEN	42c	45bc	47ab	46ab	49a
DFIFT	47a	47a	49a	50a	51a
DTWEN	49a	49a	51a	51a	53a
DTW5	52a	51a	52a	53a	54a
FULL	53ab	38ab	57a	39ab	29b
NUMP	21a	15a	22a	19a	15a
%MP	37a	36a	38a	46ab	51b

* Values within rows bordered by common letter are not different (P=.05,Waller-Duncan test).

+ Days to emergence and flowers one through 25 are means of four replications.

Other values are means of three replications.

The average number of mature pods (NUMP) as a percentage of number of full-size pods (FULL), for planting dates 1 through 4 were 6.7, 23.5, 55.3, and 45.5, respectively. The proportion of mature pods was particularly low for date one because of cool nights and early digging (90 DAP compared to 90 days after 50% emergence for the other replications). In most cases the means for the F_1, F_2, reciprocal F_1, reciprocal F_2, and the respective parental populations differed little in days from planting to twenty and twenty-five flowers.

Some F_2 segregates emerged and flowered earlier than both the parents and F_1 plants. Seedlings from the cross TxAG-2/Chico were the first to emerge and flower, followed by the cross TxAG-2/TxAG-1, which had the highest %MP. The F_2 generation of the cross Chico/Tx851856 and its reciprocal averaged earlier than for other crosses but the difference was significant only at the P=0.10 level.

Correlations Among Traits

Coefficients of correlation among the different variables were estimated for each planting date. The correlations between FULL and NUMP, and NUMP and percent mature pods (%MP) were intermediate to strong (Table 2). The correlation of NUMP and %MP varied over planting dates but, in general, was weak. Days from planting to emergence (DEMR) and to a specified flower number (DONE, DFIVE, DTEN, DFIFT, DTWEN, DTW5) were negatively correlated with FULL, NUMP, and %MP (Table 3). The coefficients of correlation for number of full-size pods and DEMR to DTW5 ranged from -0.15 to -0.51, respectively, among planting dates. The negative correlation means that fewer days to a given flower number resulted in larger numbers of full-size and mature pods at harvest. The low number of significant coefficients in date 1 compared to the other dates is attributed to the low number of mature pods at the first harvest.

Table 2. Coefficients of correlation (single plant basis) among numbers of full-size pods (Full), numbers of mature pods (NUMP), and percent mature pods (%MP) for four planting dates.

Variables	Date	"r" value
Full/NUMP	1	.39*
	2	.60*
	3	.65*
	4	.75*
Full/% MP	1	-.07
	2	.14
	3	-.48*
	4	-.18*
NUMP/%MP	1	.59*
	2	.76*
	3	.24*
	4	.42*

* Significant at P =.001 level.

Coefficients of determination indicate a much closer relationship (negative) of number of days from planting to predetermined numbers of flowers with FULL when: 1) evaluated on a plot (population within harvest date) mean basis than on an individual plant basis; and 2) the flower number is increased from first to twentieth flower (Table 4). On a plot basis the negative correlation between FULL and DONE was relatively strong, and from DFIFT to DTW5 approximated r=0.90. On an individual plant basis the relationship was significant (P=.05) but low at the DONE, and improved with increased flower number but was never high.

Heritability

Heritability estimates were computed by planting date for each cross, and mean heritabilities are presented as the average of the four estimates (Table 5). Broad-sense heritability estimates for the various traits were intermediate

Table 4. Coefficients of determination for days from planting to emergence and flowering on number of full-size pods harvested 90 days after emergence for all F_1 and F_2 populations planted May 22, June 6, and June 26 near Bryan, Texas.

	Experimental Unit	
Trait	Plant	Plot
Days to emergence	.05	.03
Days to first flower	.10*	.48**
Days to fifth flower	.12*	.68**
Days to tenth flower	.14**	.76**
Days to fifteenth flower	.16**	.79**
Days to twentieth flower	.20**	.81**
Days to twenty-fifth flower	.22**	.81**

* Significant at P=.01
** Significant at P=.0001

Table 3. Coefficients of correlation (single plant basis) for days from planting to emergence (DEMR), and first (DONE), fifth (DFIVE), tenth (DTEN), fifteenth (DFIFT), twentieth (DTWEN), and twenty-fifth (DTW5) flowers with numbers of full-size pods, and number and percentage of mature pods for each planting date at Bryan, Texas, 1987.

	DEMR	DONE	DFIVE	DTEN	DFIFT	DTWEN	DTW5
Date 1: May 19							
FULL	-0.20*	-0.20*	-0.23*	-0.29*	-0.34*	-0.40*	-0.47*
NUMP	-0.10	-0.08	-0.08	-0.06	-0.07	-0.11	-0.15*
%MP	-0.10	-0.10	-0.04	-0.06	-0.11	-0.12	-0.12
Date 2: May 22							
FULL	-0.15	-0.34*	-0.35*	-0.40*	-0.47*	-0.49*	-0.51*
NUMP	-0.08	-0.20*	-0.26*	-0.32*	-0.37*	-0.38*	-0.39*
%MP	-0.05	-0.16	-0.24*	-0.29*	-0.29*	-0.28	-0.28*
Date 3: June 8							
FULL	-0.29*	-0.29*	-0.34*	-0.37*	-0.39*	-0.40*	-0.41*
NUMP	-0.35*	-0.37*	-0.42*	-0.45*	-0.47*	-0.48	-0.49*
%MP	-0.20*	-0.22*	-0.21*	-0.22*	-0.22*	-0.21*	-0.21*
Date 4: June 26							
FULL	-0.23*	-0.40*	-0.44*	-0.47*	-0.49*	-0.49*	-0.49*
NUMP	-0.25*	-0.51*	-0.55*	-0.57*	-0.58*	-0.57*	-0.58*
%MP	-0.03	-0.04	-0.04	-0.03	-0.02	-0.01	-0.01

* Significant at P=0.0001

Table 5. Broad-sense heritability estimates for days from planting to first (DONE), tenth (DTEN), and twenty-fifth (DTW5) flowers, number of full-size pods, and number of mature pods by parental combination.*

Cross	DONE	DTEN	DTW5	FULL	NUMP
			%		
TxAG-2/Chico	46	22	49	27	54
TxAG-2/55-437	49	65	49	40	40
Tx-AG-2/Tx851856	11	37	36	41	43
TxAG-2/TxAG-1	39	53	61	40	5
TxAG-1/Chico	23	25	17	10	4
TxAG-1/55-437	37	43	60	13	28
TxAG-1/Tx851856	14	27	52	53	21
Chico/55-437	40	39	49	23	59
Chico/Tx851856	55	59	46	61	57
55-439/Tx851856	43	44	34	58	45

* Crosses and reciprocals were used in estimating heritabilities.

to low, and were slightly higher for DTEN and DTW5 than for the other traits. Although heritabilities tended to be higher for some crosses than for others, for no cross were the heritability values consistently high for all traits. In general, the heritabilities for Chico /Tx851856 tended to be high and those for TxAG-1/Chico lower than for the other crosses. High H reflects a high F_2 variance, low V_E, or a combination of both. High genetic F_2 variance would suggest differential factors for growth duration among the parents. The estimates of heritability suggest that genetic variability was present in most crosses, and that the amount of genetic variability differed among crosses. The low estimate for NUMP in the cross TxAG-2/TxAG-1 might relate to the small F_2 population size.

Segregation Patterns

The number of full-size pods and mature pods were selected *a priori* as the most accurate indicators of maturation among those evaluated. Segregation patterns for these measures were examined within planting dates, but no groupings for meaningful segregation ratios were discernible.

The number of full-size pods were combined by cross over planting dates and the mean and range in number of full-size pods by population are shown in Table 6. Data from the first planting were omitted because of the low FULL. TxAG-1 had the most full-size pods and the widest range of full-size pods among the parents, followed by Chico. TxAG-1 has small seeds that might develop faster than those of the other varieties. In some crosses (e.g. Chico X TxAG-1 and 55-437

Table 6. Means and ranges for number of full-sized pods for parents and progenies including reciprocals.

Parent/Cross	Mean	Range	Parent/Cross	Mean	Range
Chico	54	2-98			
55-437	27	4-98			
TxAG-1	62	9-139			
TxAG-2	38	1-82			
Tx851856	37	1-59			
Chico x 55-437			Chico x TxAG-1		
F_1	63	6-133	F_1	63	18-119
F_2	49	5-147	F_2	60	6-168
F_2 > Parents* =6			F_2 > Parents =1		
Chico x TxAG-2			Chico x Tx851856		
F_1	51	11-97	F_1	43	20-64
F_2	51	3-112	F_2	48	3-126
F_2 > Parents =4			F_2 > Parents =4		
55-437/TxAG-1			55-437 x TxAG-2		
F_1	52	5-109	F_1	49	16-105
F_2	45	4-138	F_2	49	1-124
F_2 > Parents =0			F_2 > Parents =8		
55-437 x Tx851856			TxAG-1 x TxAG-2		
F_1	45	25-76	F_1	47	11-193
F_2	35	2-99	F_2	45	4-108
F_2 > Parents =2			F_2 > Parents =0		
TxAG-1 x Tx851856			TxAG-2 x Tx851856		
F_1	39	14-77	F_1	44	22-83
F_2	40	1-119	F_2	39	1-105
F_2 > Parents =0			F_2 > Parents =3		

* Indicates number of plants that are outside the range of both parents.

X TxAG-2) several F_2 plants surpassed the range of both parent and F_1 plants in number of full-size pods which suggests recombination. Thus, it might be possible to select segregates that produce more full-size pods than their parents, and assumedly higher pod yield, in short seasons. In other crosses (e.g. 55-437 X TxAG-1) there was little indication that progress could be made through recombination and selection for earliness.

Combining Ability Estimates

The number of mature pods and weight of mature seeds best represented yield in this experiment. The relative combining abilities of the five parents for NUMP and weight of mature seeds (WTMS) were calculated using Design II. Neither general combining ability (GCA) as males or females, nor specific combining ability were significant (P=0.01) for either trait. This might reflect relative parental performance, as all of the lines produce nominal yields at this location.

From a practical standpoint in breeding for short growth duration conditions, assessment of potential varieties for earliness can be viewed from different perspectives. In subsistence agriculture the peanut that produces the most pods per unit area when rains cease might provide the most food if the produce were properly dried, segregated, and stored. However, immature peanuts are more subject to storage losses and *Aspergillus flavus* contamination, and the accompanying health dangers from aflatoxin. A common result is the contamination and loss of good peanuts because of excessive intermingling of immature fruit. A high percentage of mature pods at an early harvest would be desirable for storage and, accompanied with a high number of pods, would be ideal. That is the goal of peanut breeding programs with earliness as high priority. However, high %MP with low pod number is not acceptable.

From a selection standpoint, measures of both NUMP and %MP are tedious and time consuming. With limited operating budgets the breeder's choice is to make such evaluations on few populations, or greatly restrict population size. Either of these choices poses limitations on probable rate of breeding progress. Flowering traits, if adequate indicators of relative maturity, are more ideal for use by the breeder than are pod traits because notes can be made and selection imposed before digging. However, if the correlation between flowering measures and maturation is not high, erroneous selection could be imposed. According to our data, categorization of individual plants for earliness based on flowering pattern alone is not effective in offspring from crosses among early- maturing parents. The association of days to flower number and NUMP was much more effective when compared on a population basis than on individual plants (Table 2). The trait FULL might be a workable compromise as it can be estimated, or measured, rapidly and relates more closely to both NUMP and %MP than does days to flowering.

The frequency of F_2 plants with high FULL and NUMP compared to their parents was low. Those could have happened by chance; however, a low frequency of such plants might occur from transgressive segregation if the parents differ in the genetic factors that control rate of development. Parents used in this study were among the extreme of the species for short growth duration. Perhaps expectation of segregates with impressive reductions in growth-duration as compared to these parents is unreasonable. The results of this study suggest some opportunity for the selection of early-maturing recombinants, as measured by number of full-size pods at an early harvest. For example, the maximum number of full-size pods among F_2 segregates of Chico x TxAg-1, Chico x Tx851856, and TxAg-2 x Tx851856 exceeded the maximums for both the high parent and F_1 populations of the respective crosses by greater than 20%. Comparisons of the maximums with F_1's as well as parents provides some allowance for possible heterosis effects. However, the frequency of such segregates with a high FULL would likely be low. The extent of the reduction in length of growth-duration could not be estimated from this study.

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