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Inheritance of Dry Matter Deposition and Free Arginine Level in Maturing Peanuts, **Arachis hypogaea** L.

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ABSTRACT

Nine F_2 families from crosses among six peanut cultivars and breeding lines were used to investigate the inheritance of dry matter deposition and free arginine as a parameter of maturity. Results indicated that dry matter was a quantitative character governed by multiple genes, whereas free arginine level seemed to be controlled by two major genes with partial dominance for the low arginine character. Marked transgressive segregation of F_2 families below the lower dry matter parents and above the higher arginine parents was found in most of the nine crosses of various genotypes. Broad sense heritabilities were lower for the dry matter (38 to 78%) than for the level of arginine (60% to 93%). The higher broad-sense heritability of the free arginine level in these peanut cultivars examined lends theoretical support to the use of the arginine maturity index (AMI) as a measure of maturation. Correlation coefficients between dry matter and AMI varied from -.198 to -.946.

The peanut sets its fruits in an indeterminate manner; therefore, the fruits are not uniformly mature at the same time. Smith (13) described the onset of flowering as gradual with maximum flower production being reached four to six weeks after the first flowers appeared and then a gradual decrease the following four to six weeks. However, the time and rate of flowering varies among cultivars. In a Spanish cultivar, two-thirds of the flowers were produced during a one month period beginning six weeks after planting. In a Virginia runner, four-fifths of the flowers were produced during the third month after planting. Smith (13) also reported that 63% of the flowers produced pegs and one-third produced mature pods. Bear and Bailey (2) reported that a high proportion of the first 25 flowers to open developed into mature pods on plants of diverse peanut genotypes. As flowering progressed on plants of four genotypes representing a wide range of maturity, the potential for flowers to give rise to a mature pod decreased. Based upon four criteria for classifying maturity, Bailey and Bear (1) divided the peanut genotypes into four groups: very early, early, medium, and late.

Genetic studies on peanut flowering and maturation by Patel, *et al.* (10) reported that late maturation was dominant over early maturation. The F_1 was intermediate in maturation and the F_2 segregated three late- and one early-maturation. Hassan (5) reported the segregation of early, medium, and late plants in the ratio of 1:2:1. Gupton and Emery (3) used the oil pigmentation method to estimate the heritability of the maturity of fruit from specific periods in Virginia type peanuts and reported that heritability estimates ranged from 69 to 95%. Majumdar *et al.* (8) used peanut cultivars from their world collection and estimated the broad sense heritability in terms of number of days to maturity per plant and number of mature pods per plant, which were 98.6% and 60.9%, respectively.

In studies of the composition of developing peanut seed, Pickett (1) found that an increase in seed dry weight, fat and protein followed a sigmoid curve which tended to flatten as maturity approached. From weekly observations on fruit development of two cultivars, Schenk (12) found that Dixie Spanish fruits quickly ceased further development upon reaching maturity, whereas Virginia Bunch 67 fruits continued their development. The developmental period for the Spanish fruits was, therefore, considerably shorter and their maturation appeared to be more abrupt. Mason *et al.* (9) found that changes in free arginine were very dramatic and its concentration was inversely correlated with maturity of peanut kernels. Based upon the free arginine content, Young (17) developed the arginine maturity index (AMI) to estimate the maturity level of peanut fruits and to predict the optimal digging date. Young and Hammons (18) reported that cultivar and harvesting time are factors that affect the arginine maturity index. Hartzook *et al.* (4) used dry matter and free arginine parameters to study maturation in eight peanut cultivars. They found distinct groupings of AMI values for early and late-maturing cultivars, which tended to disappear as the plants approached optimal maturity. An inverse correlation between dry matter and AMI was also observed.

The objective of this study was to examine the genetic behavior of dry matter deposition and free arginine level and the relationship between these

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Table 1. Peanut cultivars (Arachis hypogaea **L.) used for genetic studies of dry matter (%) and AMI.**

Cultivar	Code	Botanical subspecies variety	U.S. market type	Maturity class
Chico	CH	fastigiata - vulgaris	Spanish	Very Early[3]
Argentine	AR	fastigiata - vulgaris	Spanish	Early[3]
Tennessee Red	TR	fastigiata - fastigiata	Valencia	Early[3]
F334A-B-14[1]	F334	hypogaea	Runner	Medium
Florunner[1]	FR	hypogaea	Runner	Medium[3]
Florida Jumbo[2]	FJ	hypogaea - hypogaea	Virginia	Late

1. Both cultivars are advanced selections from breeding programs using infraspecific hybridization and therefore are not strict hypogaea botanical varieties.
2. A large - seeded non-commercial peanut employed in breeding research.
3. W. K. Bailey and J. E. Bear (1).

Table 2. Means, ranges, coefficients of variability (C.V.%) and heritabilities (H) of dry matter of six peanut parents and their F_2 populations.

Population	Dry Matter Type*	N**	Mean***	Range	C.V.(%)	H(%)†
Parent						
CH	H	50	48.8 i	39 - 62	11.3	
AR	H	67	49.7 i	42 - 64	8.1	
TR	M+	32	48.0 i	33 - 51	10.7	
F334	M+	58	44.8 h	36 - 53	9.1	
FR	M	53	41.1 fg	32 - 50	12.6	
FJ	L	14	24.4 a	18 - 28	13.0	
F_2 generation						
CH x AR	H X H	27	43.3 gh	29 - 55	14.8	46
CH X F334	H X M+	40	40.3 efg	23 - 52	19.3	63
F334 X AR	M+ X H	73	44.2 h	21 - 55	17.1	72
AR X FR	H X M	58	39.2 def	31 - 55	14.7	38
FJ X AR	L X M	44	35.1 bc	20 - 50	20.2	75
FJ X CH	L X H	52	37.0 cd	19 - 51	19.7	68
CH X FJ	H X L	61	39.5 def	26 - 51	16.5	59
F334 X TR	M+ X M+	46	38.3 de	19 - 56	21.4	71
FJ X F334	L X M+	58	33.4 b	19 - 44	22.4	78

*Percent (%) dry matter: H - high, M+ = medium high, M = medium, L = low.
**Number of samples analyzed.
***Means followed by the same letter do not differ significantly at P = .05 according to modified Duncan's Multiple Range Test.
†Heritability (H) = $([\nabla F_2 - (\nabla p_1 \cdot \nabla p_2)^{1/2}]/\nabla F_2) \times 100$.

two characters of the peanut fruits with six peanut genotypes and F_2 populations.

Materials and Methods

Six peanut cultivars (Table 1) were the same as those used in previous genetic studies of their proteins and oils (15). The maturation of these six cultivars was classified as Chico (CH): very early; Tennessee Red (TR) and Argentine (AR): early; F334A-B-14 (F334) and Florunner (FR): medium; and Florida Jumbo (FJ): late. The nine derived F_2 populations are shown in Tables 2 and 3.

The seeds of parents and F_2's were treated with ethy-

Table 3. Means, ranges, coefficients of variability (C.V.%) and heritabilities (H) of AMI of six peanut parents and their F_2 populations.

Population	AMI Type*	N**	Mean***	Range	C.V.(%)	H(%)
Parent						
CH	L	50	53 a	25 - 80	23.2	
AR	L	67	54 a	26 - 78	25.9	
TR	M-	32	81 bc	71 - 133	22.7	
F334	M-	58	78 b	57 - 178	33.8	
FR	M	53	108 cd	56 - 154	33.1	
FJ	H	14	201 g	146 - 266	16.8	
F2 generation						
CH X AR	L X L	27	104 cd	67 - 147	29.1	81
CH X F334	L X M-	40	111 cd	53 - 317	54.7	91
F334 X AR	M- X L	73	78 b	20 - 244	48.9	75
AR X FR	L X M	58	106 cd	39 - 177	34.8	63
FJ X AR	H X L	44	150 f	76 - 320	40.1	87
FJ X CH	H X L	52	147 f	56 - 404	51.8	93
CH X FJ	L X H	61	127 def	53 - 292	44.4	87
F334 X TR	M- X M-	46	135 ef	55 - 326	46.0	60
FJ X F334	H X M-	58	139 ef	72 - 280	40.9	72

*AMI value: L = Low, M- = medium low, M = medium, H - high.
**Number of samples analyzed.
***Means followed by the same letter do not differ significantly at P = .05 according to modified Duncan's Multiple Range Test.

lene gas to enhance uniform germination (16). The seeds were space planted approximately 30 cm apart at the Southwest Branch Station, Plains Georgia on May 10, 1974. Irrigation was provided during periods of drought stress. Peanuts were dug September 12 (125 days from planting), when the very early maturing Chico had reached maturity, whereas the other genotypes were either intermediate or immature. Fruits of each of the individual plants were hand-picked and maintained separately as individual samples. All pods with soil penetration and larger than 1 mm in diameter were included in the sample for analysis. After picking, peanuts were cleaned with tap water and frozen at -18°C until analyzed.

Pods from individual plants were chopped with a Hobart Food Chopper. Four subsamples were taken; two (40 grams each) were for dry matter determination and another two (30 grams each) were for the AMI measurement. The dry matter was determined after drying at 110°C for 5 hours. The free arginine index was determined by using a continuous flow automated analytical method (17, 19). The AMI results, therefore, represented the average free arginine content of all pods on single plants.

The Kramer method (6) for multiple range test was used to examine the difference among the various populations. The frequency distribution for four F_2 populations, CH x F334, CH x FJ, F334 x TR, and FJ x F334, and their parents were selected for further examination. Broad sense heritabilities (7) of both dry matter and AMI for the F_2 generations were estimated.

Results and Discussion

DRY MATTER (DM)

The statistical characteristics of the dry matter for the six parents and nine F_2 populations are presented in Table 2. Based upon the mean dry matter values, the varieties could be classified statistically into four groups: (i) high (H), Chico, Argentine and Tenn. Red; (ii) medium - high (M+), F334; and (iii) medium (M), Florunner; and (iv) low (L), Florida Jumbo. Except Florida Jumbo, all cultivars had over 40% dry matter at 125 days from planting. Both Table 2 and Fig. 1 show that there was little overlap in the single-plant distribution for genotypes with high and low dry matter, but the distribution for both low vs. medium and medium vs. high genotypes had a considerable overlap. The distribution range of Chico was similar to that of Argentine, but their F_2 range well exceeded the lower limit of both parents producing a transgressive segregation toward lesser dry matter than either parent. The ranges of dry matter of both F334 and Tenn. Red were similar to each other. Their F_2 population, however, showed that the dry matter of individual plants produced a wide range which exceeded the range of either parent. The distribution ranges of the F_2 populations of CH x F334 and F334 x AR did not extend beyond the upper limit but did exceed the lower limit of the parent's range. The remaining F_2 populations listed in Table 2 produced ranges of dry matter located within the range of their parents. These extreme ranges and transgressive segregations in the F_2 families are thought to be due to new recombination of genetic factors for dry matter accumulation rate among their respective parents.

Modified Duncan's multiple range tests (14) for mean value difference of the dry matter among combined populations, i.e. parents and F_2's, are given in Table 2. Each of the F_2 means from CH x AR, CH x F334, and F334 x TR was significantly lower than that of respective male or female parents. Four F_2 populations, CH x FJ, FJ x CH, FJ x AR, and FJ x F334 had means located between those of the corresponding two parents. The F_2 means of AR x FR and F334 x AR were lower than that of their parents, but AR x FR did not differ significantly from its Florunner parent and F334 x AR was not significantly different from its Argentine parent in mean dry matter value.

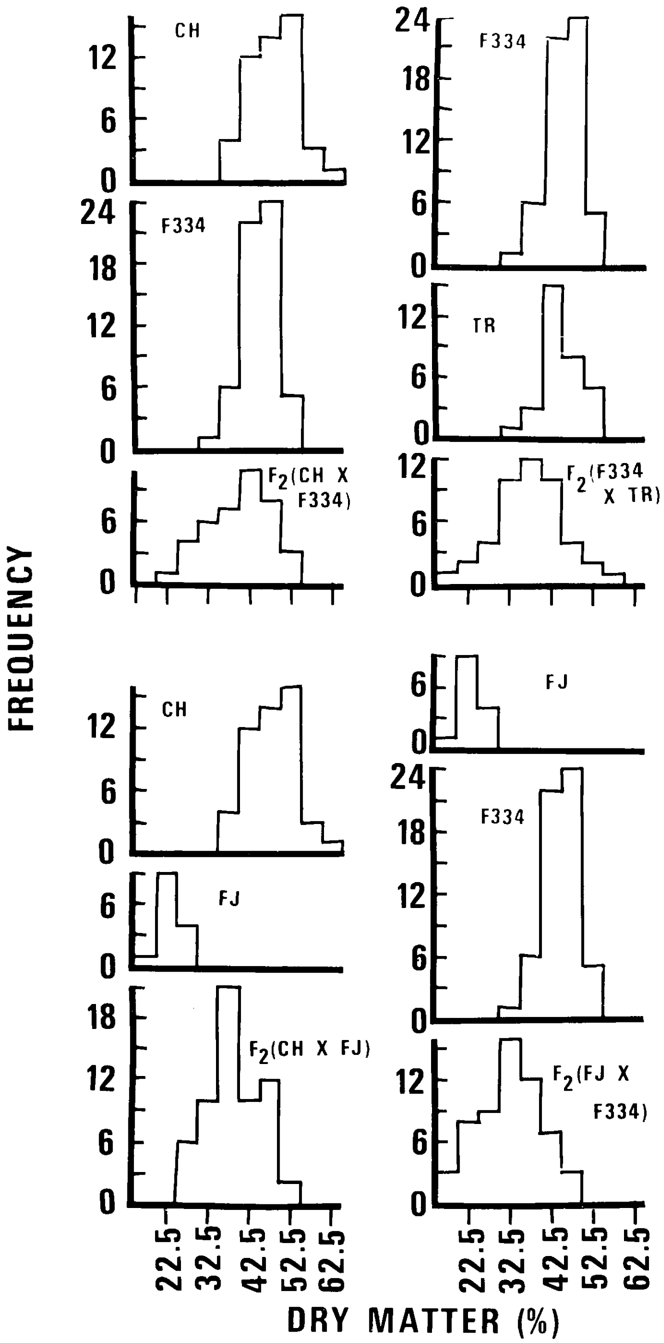

Fig. 1. Distribution of dry matter (%) of peanut fruits in the 4 F_2 populations (CH x F334, CH x FJ, F334 x TR, and FJ x F334) and their parents.

Four F_2 populations, CH x F334, F334 x TR, CH x FJ and FJ x F334 were selected for further examination of their frequency distributions of the individual plant dry matter as shown in Fig. 1. The F_2 frequency distribution of CH x FJ (H x L), F334 x TR (M+ x M+), and FJ x F334 (L x M+) appeared to be fairly normal. However, only two F_2 families, CH x FJ and FJ x F334, were distributed within the range of their respective parents. The F_2 distribution of F334 x TR showed a transgressive segregation toward both upper and lower limits. The frequency distribution of F_2 individual plants from CH x F334 (H x M+) skewed to the right for high dry matter; however, it showed transgressive segregation exceeding the left range of lower dry matter.

The coefficient of variation of dry matter for the F_2 populations varied and were much greater than for either of their parents. Among nine F_2 populations, AR x FR gave the lowest C.V. (14.7%) and FJ x F334 produced the greatest (22.4%).

The estimated broad sense heritabilities ranged from 38% (AR x FR) to 78% (FJ x F334). The low heritability and hardly detectable skewness suggested that genes for low dry matter did not express a strong dominancy over high dry matter. Thus, the dry matter content of peanuts seems to be a complex character and controlled by numerous genes acting quantitatively.

Arginine Maturity Index (AMI)

Based on AMI values, the parents, Chico and Argentine, were classified as low (L), Tenn. Red and F334 as medium low (M—), Florunner as medium (M), and Florida Jumbo as high (H) (Table 3). F334 and Florida Jumbo had the widest range of AMI values, and Chico and Argentine had the narrowest range among the parents.

Although Chico and Argentine had low AMI values, their F_2 population had an AMI significantly greater than either parent, indicating heterosis (Table 3). Also, the AMI means for two F_2 populations, CH x F334 and F334 x TR, significantly exceeded the means of the parental populations. Four F_2 populations, FJ x CH, CH x FJ, FJ x AR and FJ x F334 had AMI means located between those of their respective parents. The F_2 families of FJ x CH and CH x FJ had slightly different AMI means, but the difference was insignificant. In two crosses, AR x FR and F334 x AR, the AMI means of the F_2's were close to the low parent (Argentine) and significantly different from the medium and medium low parents, Florunner and F334, respectively.

Transgressive segregation for AMI above the high parent was evident in most F_2 populations, although transgressive segregation below the low parent also occurred in F334 x AR and possibly in F334 x TR (Table 3). It appears that recombination of genes must occur to form new genotypes

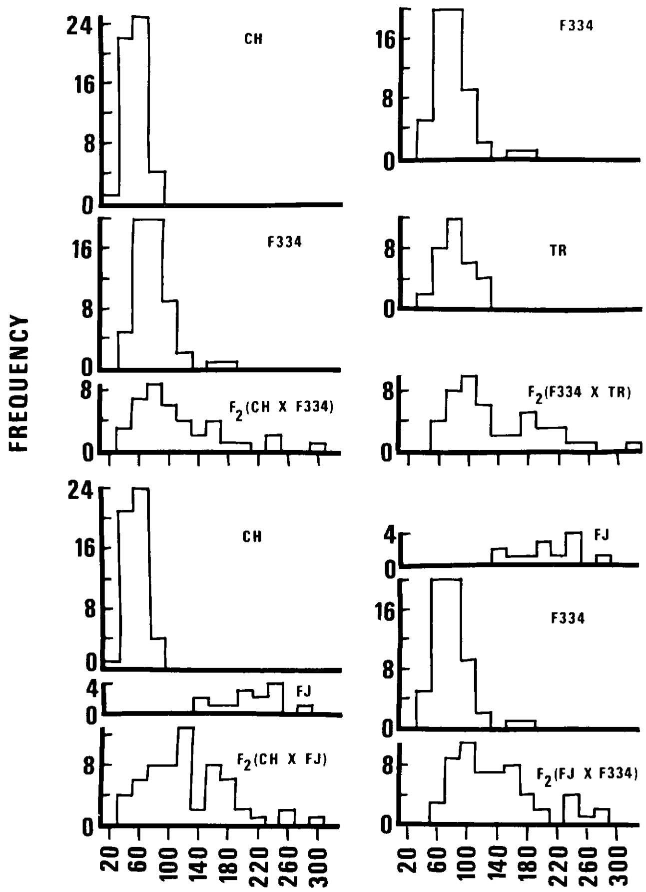

Fig. 2. Distribution of arginine maturity index (AMI) of peanut fruits in the 4 F_2 populations (CH x F334, CH x FJ, F334 x TR, and FJ x F334) and their parents.

whose effect was in the direction of higher AMI value.

For further examination on the AMI character, the frequency distribution for four of the nine F_2 populations (CH x F334, CH x FJ, F334 x TR, and FJ x F334) showed breaks in the continuity of the distributions which indicates simple inheritance (Fig. 2). AMI values from crosses of L x M— (CH x F334), M— x M— (F334 x TR), and L x H (CH x FJ) revealed the segregation of two major genes with partial dominance for low AMI. Chi-square tests indicated that there was a satisfactory fit to a ratio of 15 (L + M AMI):1 (H AMI), with the probability of exceeding 50% of these crosses. In crosses of H x M— AMI (FJ x F334), the frequency distribution fell into the two distinct groups with a probability for the 15:1 segregation ratio between 0.05 and 0.10 although too many plants appeared to have high AMI values. Three of the five F_2 populations, whose frequency distributions were not plotted (FJ x CH, F334 x AR and FR x AR), also gave a 15:1 segregation with probabilities of 50, 50 and 75%, respectively. The distributions of the F_2's from the remaining two crosses (CH x AR and AR x FR), however, generated a continuum of values.

Our results suggest that the high AMI parents differ from both the medium and low AMI parents by two major genes. Minor genes and their interaction may also play an important role on the inheritance of the level of free arginine in peanuts.

In F_2 populations, in which the AMI from individual plants was measured, the estimates for broad sense heritability ranged from 60 to 93% (Table 3). The AMI character in peanuts, therefore, exhibited a much higher heritability than

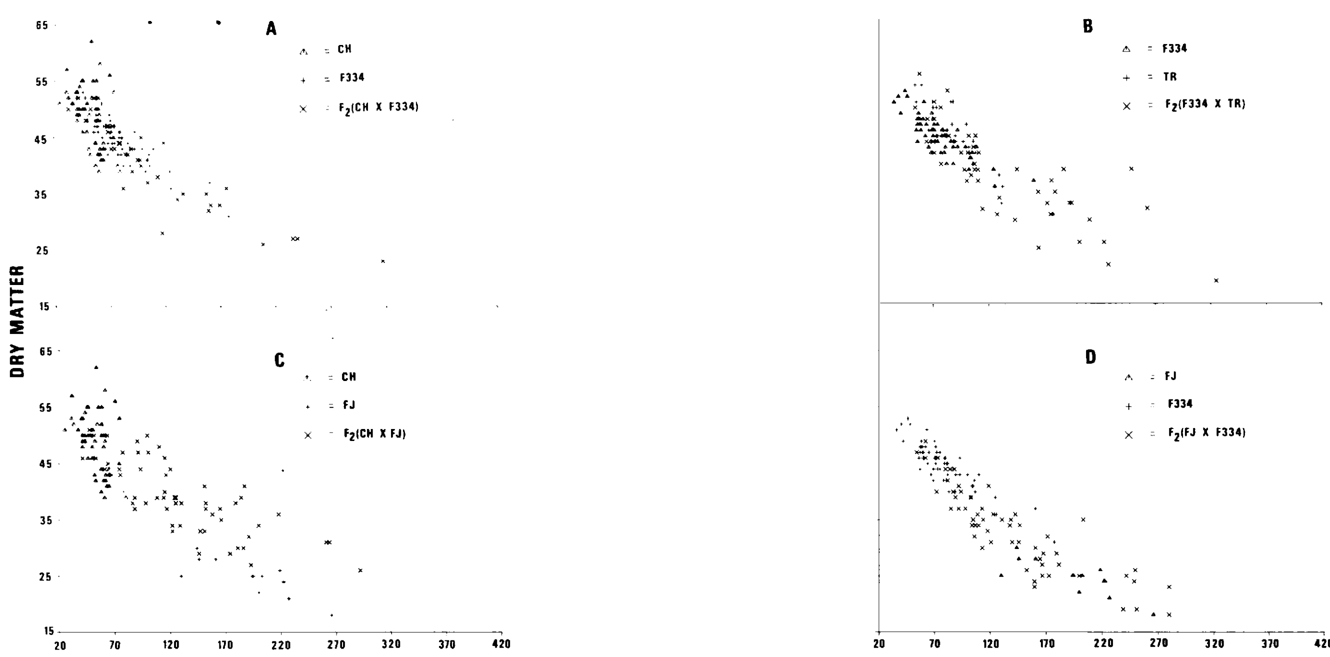

Fig. 3. Relationship between dry matter and AMI for four F_2 peanut populations and their parents.

did the dry matter as might be expected since dry matter is composed of three major components (oil, protein and carbohydrate) and many minor components. Such high heritability with the skewness to the lower AMI values as shown in Fig. 2 suggests that the low AMI was partially dominant over the high AMI character.

Relationship Between Dry Matter and Arginine Maturity Index

A negative relationship between dry matter (DM) and arginine maturity index (AMI) was revealed in Fig. 3. Two F_2 families, CH x F334 (H DM • L AMI x M DM • M— AMI) and F334 x TR (M DM • M— AMI x M DM • M— AMI), showed marked transgressive segregation toward the direction of L DM • H AMI. However, most of the F_2 plants overlapped the distribution of the two parents. In the crosses CH x FJ (H DM • L AMI x L DM • H AMI) and FJ x F334 (L DM • H AMI x M DM • M— AMI), the F_2 plant distribution bridged the gap between their parents. These two populations showed less transgressive segreation toward L DM • H AMI than did the other two discussed above. All four F_2 populations showed that the plants did not fall into distinct groups, instead they ranged from high dry matter with low AMI to low dry matter with high AMI. There was, however, an indication of possible gene recombination that resulted in an isolated group of F_2 plants with low dry matter — high AMI from the crosses CH x F334, CH x FJ, and FJ x F334.

The present results suggest that both DM and AMI analyses of low generation populations could be used in peanut breeding to screen for any desirable period of fruit maturation.

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