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Relationship of Seed Mass to Oil and Protein Contents in Peanut (*Arachis hypogaea* L.)[1]

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ABSTRACT

Seed mass, oil and protein contents are important quality traits in peanut (Arachis hypogaea L.). Sixty-four genotypes were grown for four seasons to study genetic variation and character association between these three traits. Graded seed samples of 33 genotypes were further studied for possible variation within genotype among grades for oil and protein contents. No significant association of seed mass with percent oil or protein contents was observed among the 64 genotypes. However, oil and protein contents were significantly negatively associated. Oil content variation within a genotype showed a significant linear increase as the seed mass increased in the graded samples, but no such relationship was observed with protein content. Genotypes with desirable traits for confectionery and/or oil types were identified and may be used for germplasm enhancement.

Key Words: *Arachis hypogaea*, seed quality, correlations, seed weight, seasonal variation.

The peanut or groundnut (*Arachis hypogaea* L.) seed contain an average of 44% oil and 25% protein. Amongst 6840 germplasm accessions evaluated at ICRISAT Center, oil content ranged from 32 to 55% and protein ranged from 16 to 34% (9, 10). Previous studies reported narrow ranges of genetic variation for these traits (4, 16, 19, 20, 23, 26, 27, 29) in cultivated *A. hypogaea*, but variation of 46-63% in oil content in other *Arachis* species (4). Seed mass, oil and protein contents largely determine the end use of a peanut genotype whether for direct consumption or for oil extraction. Peanut cultivars with large seed mass and low oil content, for health consideration, are preferred for confectionery use. Seed mass is not an important trait for oil types.

Seed mass variation within a genotype may influence oil and protein contents because of differing maturity and sizes resulting from the indeterminate flowering habit of the peanut plant. Limited studies on the effect of seed mass variation on oil content in graded samples within genotypes showed high oil content in the medium-sized seed (12, 17).

An understanding of the relationship between 100-seed mass and oil and protein contents will help formulate an effective procedure for the selection of desirable traits in the breeding for confectionery and/or oil types. There are conflicting reports on the nature of association between these traits (5, 15, 16, 18, 26), which are largely based on a single-season evaluation of limited numbers of genotypes. A need to acquire more information on the nature of the associations exists between these traits.

The objectives of the present study were to (a) identify genotypes with high seed mass, low oil, and high protein for use in a confectionery breeding program, (b) identify genotypes for use in breeding for high oil content, (c) study the nature of the association of 100-seed mass with oil and protein contents, and (d) study the effect of seed mass variation on oil and protein contents in the graded seed samples among and within genotypes.

Materials and Methods

Sixty peanut genotypes together with three control cultivars (JL 24, Kadiri 3, and M 13) and a small seeded germplasm line ICG 4906 were selected for this study. These genotypes were bred for high pod yield and adaptation to high and/or low input production system. The trial was grown in an 8 x 8 lattice design with three replications under high inputs in two rainy (1986 and 1987) and two postrainy (1986/87 and 1987/88) seasons at ICRISAT Center. Four-row plots, 4 m in length, with plants spaced at 30 x 10 cm were adopted. The high inputs included 60 kg P_2O_5 ha^{-1}, irrigation, protection against insect pests and foliar diseases, and gypsum applied at peak flowering (400 kg ha^{-1}).

In all four seasons, sound mature seed samples were taken at harvest from replicated plots and 100-seed mass (g) was recorded. Seed were analyzed for oil and protein content. After taking sound mature seed samples, the remaining fruit from all the three replications of each genotype were bulk-shelled and a random seed sample of 1 kg was drawn for grading. Seed grading was performed on samples from the two postrainy seasons (1986/87 and 1987/88) and the 1988 rainy season only. A peanut screen 'SHAKER' (115 V, 60 HZ, 1 phase, 1725 RPM) was used for seed grading. The SHAKER was run for 2-3 min to ensure that seed had passed through screens of specific sizes. Sieves of six

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different perforations were used to grade the seed lot into seven grades as described below.

Grade	Screen size (mm)	
	Rides	Passes through
I	-	6.0 x 19
II	6.0 x 19	6.4 x 19
III	6.4 x 19	6.7 x 19
IV	6.7 x 19	7.1 x 19
V	7.1 x 19	7.5 x 19
VI	7.5 x 19	7.9 x 19
VII	7.9 x 19	

Of the 64 genotypes graded, only 33 had sufficient seed in all seven grades in three seasons for combined analyses. One hundred seeds were sampled at random from each of the seven grades of 33 genotypes and weighed prior to chemical analyses.

Nitrogen content of seed samples was determined according to the procedure of Singh and Jambunathan (24). Approximately 20 g of peanut seed were ground in a Krups KM75 (Robert Krups, 5650 Solingen 19, Postfach 190460, West Germany) blender and 50-60 mg of ground material were used for nitrogen determination. Nitrogen values were converted to crude protein using a factor of 5.46. Oil contents of intact peanut seeds were determined using a slight modification of the procedure of Jambunathan *et al.* (11). Readings were taken on previously oven-dried (110C, 16 h) samples. All oil values were calculated and expressed on a uniform 5% seed moisture content basis.

Combined analysis of variance over four seasons was based on a lattice design to measure genotype, season, and genotype x season effects on 100-seed mass, and oil and protein contents. Seasonal effects were assumed to be random, whereas genotype effects were assumed to be fixed. Genotypic and phenotypic correlations were estimated following the methods described by Al-Jibouri *et al.* (1). Three season's data on 100-seed mass, oil and protein contents of the seven grades of the 33 genotypes were statistically analyzed, using seasons as replications, in randomized block design. Each of the seed characteristics were regressed on variable grades (I-VII) for all 33 genotypes pooled together to obtain common trends (linear regression) and for each genotype separately to assess whether there were genotype differences in trends (regression for comparison). The measure of failure of the trends to explain all of the variability attributable to grades was also made, being referred to as "lack of fit".

Correlation of 100-seed mass with oil and protein content was estimated over grades and seasons for individual 33 genotypes as well combined over genotypes, seasons, and grades.

Results and Discussion

A combined analysis of data recorded on 64 genotypes over four seasons revealed highly significant genotype, season, and genotype x season effects for all the three characters studied (Table 1). Partitioning of total estimated variance indicated that genotype effects accounted for 72% variation in 100-seed mass, and for 44% and 45% for oil and protein contents, respectively. Percent contribution of genotype x season effects to the total variation in these traits was of less importance, though these effects were highly significant.

Among the 64 genotypes, mean 100-seed mass across four seasons ranged from 17.2 to 82.3 g, while percent oil and protein contents varied between 44.8 and 50.5 and 20.7 and 28.1% respectively (Table 2). While a remarkable increase in the mean 100-seed mass (44%) was observed in the postrainy season, differences in mean oil content were negligible between rainy and postrainy seasons. However, the mean protein content registered an increase of 10% in the postrainy compared with the rainy season. Of the three controls, JL 24 had an average of 28% protein and 45% oil content, and Kadiri 3 had 23% protein and 48% oil. The wide range of variation obtained for 100-seed mass in this study is similar to that recorded by Sangha (19, 20). The narrow ranges of variation for oil and protein contents reported here agree with observations by previous workers (3, 4, 8, 16, 23, 26, 27, 29). The small-seeded genotype, ICG 4906 (100-seed mass, 17 g), had oil content similar to many medium- and large-seeded genotypes.

Table 1. Pooled analysis of variance for 100-seed mass, percent oil and protein contents in 64 peanut genotypes.

Source	df	Mean square		
		100-seed mass (g)	Oil (%)	Protein (%)
Seasons (S)	3	7104.0**	45.1**	125.9**
Block (adjusted)	24	14.5	1.3	1.5
Genotype (G)	63	360.7**	8.6**	7.9**
G x S	189	22.2**	1.3**	1.2**
Pooled error (e)	420	5.2	0.5	0.4
Variance estimates				
Var. (G)		28.21	0.61	0.56
Var. (G x S)		5.66	0.27	0.27
Var. (e)		5.20	0.50	0.40

**Significant at 0.01 probability level.

A highly significant negative correlation was observed between oil and protein content in each season and also when combined over four seasons (Table 3). Similar observations were reported in studies conducted by Tai and Young (26), and Chiow and Wynne (5). Layrisee *et al.* (15) reported a significant but low positive genotypic association between oil and protein contents. However, the phenotypic correlation between these two traits in their study was nonsignificant and similar to those reported by Makne and Bhale (16). No association between 100-seed mass and oil or protein contents over seasons was noted in this study. However, in the 1987/88 postrainy season, a significant positive phenotypic correlation between 100-seed mass and oil content, and a significant negative phenotypic correlation between 100-seed mass and protein content were found. Studies conducted by Rao *et al.* (18) and Layrisee *et al.* (15) also reported no correlation between 100-seed mass and oil or protein content.

Increased oil content was associated with increase in 100-seed mass in the seven graded seed samples of the 33 peanut genotypes (Table 4)). No such trend was observed in the case of mean protein content. Previous studies (12, 17), however, reported high oil content in the medium-sized seed of the graded sample of peanut genotypes.

Combined analysis of variance of the graded seed samples of 33 genotypes over three seasons also revealed highly significant season and genotype effects for all three characters (Table 5). Sources normally attributable to grades and genotypes x grades interactions were repartitioned into a common linear trend (regression), individual genotype trend deviations from the common trend (regression comparison), and a failure of the regressions to explain all of the variation attributable to grade and genotype x grade sources (lack of fit). The highly significant regression (linear) source (Table 5) indicated strong association ($r = 0.98^{**}$, Table 6) between oil content and 100-seed mass of graded seed samples among genotypes. It is worth noting, based on mean square

Table 2. Mean and range of variation for 100-seed mass, percent oil and protein contents among 64 peanut genotypes.

Character	Season	Mean	Range	Control mean			
				Kadiri 3	JL 24	M 13	SE±
100-seed mass (g)	Rainy 1986	42.2	16.0 - 74.4	40.9	44.5	56.4	2.58
	Rainy 1987	39.1	14.4 - 64.2	41.8	41.1	51.0	1.06
	Postrainy 1986/87	59.3	17.9 -102.6	56.4	53.6	53.2	2.21
	Postrainy 1987/88	58.3	20.4 - 96.5	53.9	51.9	52.6	2.87
	Over 4 seasons	49.7	17.2 - 82.3	48.3	47.8	53.3	1.15
Oil (%)	Rainy 1986	48.6	43.7 - 50.7	48.0	45.8	47.4	1.10
	Rainy 1987	47.2	42.6 - 51.5	46.7	42.6	48.5	0.53
	Postrainy 1986/87	47.4	43.7 - 50.7	47.3	45.2	45.1	0.47
	Postrainy 1987/88	48.9	43.5 - 51.3	50.0	46.0	44.6	0.50
	Over 4 seasons	48.0	44.8 - 50.5	47.9	44.9	46.4	0.35
Protein (%)	Rainy 1986	22.5	18.3 - 28.7	23.0	28.7	22.9	0.91
	Rainy 1987	22.5	18.9 - 29.2	22.5	29.2	22.3	0.53
	Postrainy 1986/87	25.4	22.3 - 29.2	25.1	27.9	22.4	0.44
	Postrainy 1987/88	24.3	21.1 - 27.5	21.1	26.7	21.9	0.62
	Over 4 seasons	23.7	20.7 - 28.1	22.9	28.1	22.4	0.32

comparison with the total residual mean square, that the common linear trend adequately explains the relation of the traits to the grades and that this trend seems to hold for all genotypes, there being little or no evidence of genotype trend differences or lack of fit.

Correlations of 100-seed mass with oil content (%) combined over grades and seasons for 33 individual genotypes, and combined over grades/seasons/genotypes, are presented in Table 6. Highly significant positive correlations (r=0.88** to 0.99**) were observed between 100-seed mass and oil content over grades/seasons among the 33 genotypes when analysed separately or combined over genotypes/grades/seasons (r=0.98**).

Peanut genotypes which showed significant superiority over controls for seed mass, oil, and protein contents, have

Table 3. Genotypic and phenotypic correlation coefficients among 100-seed mass, percent oil and protein contents in 64 peanut genotypes.

Season/Year		Correlation		
		100-seed mass/oil (%)	100-seed mass/ protein (%)	Oil/protein (%)
Rainy 1986	Genotypic	-0.01	0.11	-0.63
	Phenotypic	0.03	0.08	-0.55**
Postrainy 1986/87	Genotypic	0.02	0.00	-0.56
	Phenotypic	0.04	0.01	-0.50**
Rainy 1987	Genotypic	0.12	0.02	-0.67
	Phenotypic	0.13	0.01	-0.63**
Postrainy 1987/88	Genotypic	0.21	-0.22	-0.38
	Phenotypic	0.21*	-0.19*	-0.37**
Combined over seasons	Genotypic	0.01	-0.05	-0.71
	Phenotypic	0.04	-0.05	-0.61**

*,** Significant at 0.05 and 0.01 probability levels, respectively.

Table 4. Mean and range of variation for 100-seed mass, percent oil and protein contents in the graded seed samples of 33 peanut genotypes.

Grade	100-seed mass (g)		Oil (%)		Protein (%)	
	Mean	Range	Mean	Range	Mean	Range
I	27.1	19.8 - 32.5	43.4	39.9 - 47.2	24.0	20.7 - 28.1
II	33.5	26.4 - 42.3	45.0	41.9 - 48.7	23.9	19.8 - 27.8
III	37.9	32.7 - 47.1	46.2	42.8 - 49.4	24.1	20.2 - 28.6
IV	43.1	35.4 - 51.9	47.4	44.5 - 50.1	24.1	20.3 - 28.8
V	48.4	41.4 - 54.7	48.4	45.0 - 50.9	24.0	20.3 - 27.9
VI	53.9	46.2 - 61.6	49.2	46.9 - 52.3	23.8	20.4 - 27.7
VII	62.5	51.3 - 72.8	49.8	45.8 - 51.9	23.6	20.2 - 26.9
SE	±0.46		±0.15		±0.16	

Table 5. Covariance analysis (mean square) of 100-seed mass, percent oil and protein contents in terms of their linear relation to grades for 33 peanut genotypes.

Source	df	100-seed mass (g)	Oil(%)	Protein (%)
Seasons	2	1638.7**	271.5**	264.3**
Genotypes	32	201.6**	40.1**	45.8**
Regression (linear)	1	87713.4**	3181.3**	8.7
Regression comparison	32	35.2	3.1	1.3
Lack of fit	165	9.7	1.0	1.1
Residual	460	21.3	2.4	2.5

** Significant at 0.01 probability level.

Table 6. Correlations (r) of 100-seed mass with oil (%) in the graded seed samples of 33 peanut genotypes.

Correlation between 100-seed mass (g) and oil (%) combined over grades and seasons			
Genotype	r	Genotype	r
ICGV 86369	0.95**	ICGV 87135	0.96**
ICGV 86391	0.96**	ICGV 87139	0.94**
ICGV 86414	0.94**	ICGV 87144	0.99**
ICGV 86415	0.94**	ICGV 87151	0.93**
ICGV 86451	0.99**	ICGV 87153	0.91**
ICGV 86529	0.97**	ICGV 87154	0.95**
ICGV 86553	0.97**	ICGV 87170	0.93**
ICGV 86554	0.95**	ICGV 87173	0.96**
ICGV 86961	0.94**	ICGV 87186	0.99**
ICGV 86962	0.98**	ICGV 87187	0.97**
ICGV 87121	0.97**	ICGV 87188	0.97**
ICGV 87126	0.99**	ICGV 87870	0.95**
ICGV 87127	0.96**	ICGV 87871	0.96**
ICGV 87130	0.99**	ICGV 87872	0.94**
ICGV 87131	0.95**	ICGV 87874	0.95**
ICGV 87133	0.99**	ICGV 87875	0.95**
		JL 24	0.88**
Correlations between 100-seed mass (g) and oil (%) combined over grades/seasons/genotypes			0.98***

ICGV = ICRISAT Groundnut Variety.
**Significant at 0.01 probability level.

been identified (Table 7) for desirable end uses and may be used in germplasm enhancement.

Many peanut breeding programs around the world are involved in the development of high-yielding genotypes for oil content and/or for confectionery types. Large-seeded peanut genotypes with low oil content may be preferred for confectionery purposes for health consideration (6), whereas genotypes with high oil content are used for oil extraction. The negative correlation between oil and protein content and the lack of any association of these two traits with 100-seed mass revealed that it is possible to breed large-seeded peanut genotypes with low oil and high protein content. Seed mass is not as important in genotypes developed for oil extraction. However, due to a positive association between seed mass and pod yield (2, 7, 13, 14, 21, 22, 25, 28) and lack of association between seed mass and oil content as observed in this study, it should be possible to select indirectly for high pod yield by selecting for large seed mass in early-generation segregating material generated for developing oil-type genotypes. The positive association between oil content and 100-seed mass of the graded seed samples among 33 genotypes reemphasizes the need to develop genotypes with uniform seed maturity to realize the full genotype potential in oil content.

Table 7. Peanut genotypes with desirable traits.

Genotype	Growth habit[1]	Mean 100-seed mass (g)	Mean oil (%)	Mean protein (%)
(A) For confectionery use				
ICGV 86571	VB	82.3	44.8	27.2
ICGV 86577	SB	75.4	45.6	26.5
ICGV 86551	VB	61.8	45.3	24.5
(B) For oil extraction				
ICGV 87871	SB	46.2	50.5	23.2
ICGV 87873	SB	52.6	50.3	23.1
ICGV 86529	SB	52.1	50.1	22.0
ICGV 87126	SB	50.4	50.0	22.1
(C) For confectionery and oil extraction				
ICGV 86564	VB	75.5	49.7	22.9
ICGV 86553	SB	59.1	49.2	21.9
Control				
Kadiri 3	VB	48.3	48.0	22.9
JL 24	SB	47.8	44.9	28.1
M 13	VR	53.3	46.4	22.4
SE		±1.15	±0.35	±0.32
Overall mean		49.7	48.0	23.7

1. SB=Spanish Bunch; VB=Virginia Bunch; VR=Virginia Runner.

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