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Inheritance of seed quality traits in groundnut (*Arachis Hypogaea* l.)

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Abstract

Development of groundnut genotypes with large seed size and seed weight and improved seed quality attracts consumers' immediate attention. Knowledge of the genetics system controlling expressions of these traits facilitates the choice of the most efficient breeding and selection procedure. A study of the nature and magnitude of gene effects in groundnut (*Arachis hypogaea* L.), utilizing three parameter additive-dominance model,where a confectionery variety (Oboshie) was crossed with two non-confectionery high yielding varieties (Jenkaah and Nkosour). Six generations of parents, first filial and second filial generations, backcrosses 1 and 2 (P_1, P_2, F_1, F_2, BC_1 and BC_2) were studied for two quantitative traits (seed size and seed weight) in Oboshie x Jenkaah and Oboshie x Nkosour crosses. The study indicated that the additive-dominance model was adequate to explain the mode of inheritance of seed size in both crosses. The net additive gene effect contributed significantly to the inheritance of seed size; therefore, suggesting that selection for improvement of seed size could be accomplished in the F_2 generation in both crosses. The net dominance effect was positive indicating dominance towards the direction of the larger seed parent. Additive gene effects contributed significantly to the inheritance of seed weight per plant in Oboshie x Jenkaah cross, and magnitude of the net additive effect was higher than the dominance gene effect. Dominance value was however positive indicating direction towards the heavier seed parent. The simple additive-dominance model was inadequate to explain the mode of inheritance of seed weight per plant for Oboshie x Nkosour cross, and therefore suggested the presence of non-allelic interaction in the inheritance of its seed weight per plant. The result suggested that selection for seed weight per plant for Oboshie x Nkosour could be achieved through indirect selection for a component trait such as seed size than direct selection for seed weight itself. The additive genetic effects observed for both traits will enhance pure line breeding.

Keywords: Arachis Hypogaea L.; Seed Size; Seed Weight; Filial Generation; Additive Dominance

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1. Introduction

Seed quality can have a major impact on potential crop yield and nutritional value. Seeds carry the genetic trait incorporated by years of breeding and selection to create varieties that are adaptable to specific production environments and will produce high yields and quality products.

Groundnut is an important oilseed crop around the world. It is ranked as the second most important cultivated grain legume, fourth largest edible oilseed crop and third most important vegetable protein in the world (Shilman et al., 2011; Lucas, 1979). It is extensively grown throughout the Semi-arid tropics (SAT) of Asia, Africa and North and South America, with its global production of 38 million tons from 24 million hectare area (FAOSTAT, 2011). Groundnut is grown primarily for human consumption and it is a rich source of oil (40–50%), proteins (20–50%) and carbohydrates (10–20%), and also a good source of variety of essential vitamins and minerals (Belamkar et al., 2011). Every part of the groundnut plant is used in some way: kernels for human consumption, branches and leaves as fodder for cattle, and nitrogen fixed from its root as nutrient for the soil.

Ghana is one of the leading producers of groundnut in the world. Ghana ranked 10th (530,887 MT of in-shell groundnut) in production volume in the world and 4th in Africa, right behind Nigeria, Senegal and Sudan (FAOSTAT, 2011). Groundnut is the most important legume crop grown in Ghana in terms of the total production and value (Tsibey et al., 2003). Agro ecologically, groundnut is grown mostly in the northern savanna zone, where the highest yield of 1.92 Mt/ha has been recorded (MoFA, 2011). The Northern and Upper West Regions produced about 80 percent of the nation's total groundnut production. Groundnut is commonly grown alongside major crops such as maize, yams and millet (Tsibey et al., 2003).

Like the rest of Sub-Saharan Africa, groundnut is a valuable cash crop in Northern Ghana and a food staple for millions of Ghanaians (MoFA, 2011). Groundnut is also processed into paste (butter) and widely used by Ghanaians to make soup, stews, and cereal mixtures (Asibuo et al., 2008). In the Northern Region, women process the meal into cakes which are consumed as snacks (kulikuli) or further processed into powdered form (kulikuli zim). Groundnut cake from industrial oil processing is mostly used for human and livestock feed especially in the South (Awuah et al., 2009).

Despite the recognition of Ghana as one of the leading producers of groundnut in the world, yield on farmers field continue to be below the attainable yield of 2-3 Mt/ha due to biotic and abiotic factors including unstable rainfall patterns, diseases and pest infestation, lack of genetic quality seeds and favourable agronomic practices. These problems have led to poor quality seeds, low yield and low marketability of groundnut in the international market.

The seed quality aspect of groundnut is gaining importance because of increased use of groundnut as a food crop due to chronic shortage of pulses and increasing protein malnutrition among the burgeoning, undernourished, poverty stricken population in developing countries. Hence, more emphasis is given to improve and exploit groundnut as a food crop to make its farming more competitive and remunerative.

Dwivedi et al. (2000) noted that quality of edible groundnut seed is determined by various physical, sensory, chemical and nutritional factors. Physical factors include; integrity of seed testa, seed size, and shape, blanching efficiency and the integrity of the seed at the time of processing. Sensory factors include colour,

texture, flavor, and wholesomeness. Chemical and nutritional factors include oil and protein contents, amino acid and fatty acid composition, carbohydrate, minerals and vitamins.

Edible groundnut kernels are generally referred to as confectionery groundnut, export quality groundnut, large/bold seeded groundnut and handpicked selected groundnut. The quality requirement of confectionery groundnut is more stringent and distinctly different from groundnut as an oilseed crop. This requires additional efforts to develop confectionery grade varieties with high protein and sugar, low oil and reduced aflatoxin risk, large elongated kernels with tapering ends, pink or tan seed colour, ease of blanching and high oleic/linoleic acid ratio (O/L) is preferred (Nigam et al., 2000).

The exploitation of genetic control of seed quality traits through hybridization and selection is the primary focus of this work. Knowledge of the genetic systems controlling expressions of these characters facilitates the choice of the most effective breeding and selection procedure. The aim of this work was therefore to determine the mode of inheritance for seed size, protein and oil content in groundnut.

2. Materials and methods

2.1. Description of experimental site

The study was conducted at both the Faculty of Agriculture of Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, and Center for Scientific and Industrial Research (CSIR) - Crop Research Institute (CRI), Fumesua, Kumasi (6° 45´ N, 1° 25´ W) from February 2012 to May, 2013. Two stages of hybridization trials were conducted in pots at KNUST, whilst an evaluation experiment was done on the upland research field at CSIR-CRI, Fumesua.

The upland research field area falls within the semi-deciduous rain forest zone and is characterized by a bimodal rainfall pattern, from April to July and then from September to December, with an average annual rainfall of 1500 mm. The soil is classified under Kumasi series locally called Ferric Acrisol or forest ochrosols (FAO/UNESCO legend, 1990). Study area was previously planted to rice

2.2. Description of parental plants

The basic material for the present study consisted of three groundnut parents which included; Oboshie, Nkosour and Jenkaah. These were bred at the International Crop Research Institute for Semi-Arid Tropics (ICRISAT), Patancheru, India. Oboshie was screened and evaluated for confectionary purposes, and was released in 2012 at CSIR-CRI, Kumasi. Nkosour and Jenkaah were screened and evaluated for resistance to rosette virus and other field diseases and are also high yielding

2.3. Seedling establishment

Seeds were sown in plastic bowls/ pots measuring 45 cm (top diameter) x 39 cm (base diameter) x 12 cm (height) with drainage holes. The pots were filled with 16.5 kg sterilized soil in the ratio of two parts top soil

or black soil to one part river sand. Two seeds were planted into each pot and thinned to one plant per pot one week after germination. Sowing of parents was staggered over a period of three days to synchronize flowering.

2.4. Hybridization experiments

2.4.1. Experiment 1

This was done by crossing parents and F_1's to develop progenies for F_1, F_2 and backcrosses. This operation was done in two stages as follows: The first stage involved crosses of parents to develop F_1 population. This included both straight and reciprocals. Two straight crosses viz.; Oboshie x Nkosour, Oboshie x Jenkaah and their reciprocals i.e., Nkosour x Oboshie, Jenkaah x Oboshie were done. The second stage involved crosses of F_1's with either parents to develop backcrossed progenies and selfing of F_1's to develop F_2 population.

Eight backcrosses viz.; (Nkosour x Oboshie) x Nkosour, (Nkosour x Oboshie) x Oboshie, (Jenkaah x Oboshie) x Jenkaah, (Jenkaah x Oboshie) x Oboshie, (Oboshie x Nkosour) x Oboshie, (Oboshie x Nkosour) x Nkosour, (Oboshie x Jenkaah) x Oboshie, (Oboshie x Jenkaah) x Jenkaah. F1's of the four crosses were selfed to obtain F2 generation.

2.4.2. Experiment 2

This was done to evaluate parents, F_1's, F_2's and backcrosses. A field experiment was conducted during the dry season on 14th December, 2012 at the CSIR-CRI, Kumasi, to study the genetic control of seed quality traits in groundnut. The experiment consist of three parents (Nko, Jen and Obo), four F_1's (Nko x Obo, Obo x Nko, Jen x Obo and Obo x Jen), eight backcrosses (Nko x Obo) x Nko, (Nko x Obo) x Obo, (Obo x Nko) x Obo, (Obo x Nko) x Nko, (Jen x Obo) x Jen, (Jen x Obo) x Obo, (Obo x Jen) x Obo, (Obo x Jen) x Jen and four F_2's (Nko x Obo) selfed, (Obo x Nko) selfed, (Jen x Obo) selfed, and (Obo x Jen) selfed.

2.5. Field experimental design and agronomic practices

The experimental area was prepared to fine tilth before planting was done. Experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Plot size varied by generation. Each plot was a single ten-plant row for F_1 and backcross generations, and six ten-plant rows for parent and F2 generations. Rows were 2.0 m long with a between and within row spacing of 30 x 20 cm respectively. NPK-15:15:15 ($40kgha^{-1}$) was applied two weeks after germination and gypsum ($40kgha^{-1}$) applied at 50% flowering. Mechanical and manual irrigation was done on a regular basis. Other field agronomic practices were done as and when necessary.

2.6. Data collection

At maturity, groundnut was harvested and data collected from all generations (P. F_1. F_2. BC_1, BC_2 and their reciprocals). Pod length and width, seed length and width were measured from 10 dried mature seeds

selected at random using vernier calliper. 100 dried mature seeds were selected at random from seedlot of each treatment and weight recorded in grams. Seed size was calculated by ratio of seed length to seed width on 10 matured seeds selected at random.

Oil content was determined using soxhlet method as described by Jambunathan et al., (1985). Protein content was determined by measuring nitrogen concentration using Technicon auto analyzer (Singh and Jambunathan, 1980). 0.5g of defatted sample was taken and 12.5 ml of distilled water was added and kept it for extraction for 8-10 hours. Sample was centrifuged for 15 minutes at 10000 rpm by using centrifuge. Supernatant was decanted into separate test tube and made up to known volume. The extracted sample was further used for estimation of proteins. A factor of 5.46 was used to convert nitrogen into crude protein content.

2.7. Statistical analysis

Data for traits were subjected to Analysis of Variance (ANOVA) using Genstat statistical package (Discovery Edition 4). Least Significant Difference (LSD) at 5% was used to determine the significant differences among the means of the various generations.

Generation mean analysis using scaling test A, B and C proposed by Mather (1949) and joint scaling test of Cavalli (Cavalli, 1952) was followed using Microsoft Excel to determine the genetic control of seed size, and seed weight.

The A, B and C scaling tests were solved individually to check the adequacy of the additive-dominance model by their deviation or equality to zero. The model was adequate when all of each individual value equal to zero. A corresponding standard error (SE) for each test was used as a denominator to determine the calculated t-test. Significance of the values of A, B, and C was determined by comparing the calculated and tabulated t values, at a degree of freedom (df) determined by summing up the individual df of each parameter. Formulas to determine individual A, B and C values, their corresponding standard errors and test of significance were as shown in Table 1, where; P1, P2, F1, F2, B1 and B2 are the generation mean, VP1, VP2, VF1, VF2, VB1 and VB2 are variance of the mean of the generations involved in the test, t_A, t_B and t_C are the calculated t values and SE the standard error. Significance of each parameter (A, B and C) from zero is concluded when the t calculated is higher than the t tabulated. Cavalli's joint scaling test has the advantage of testing goodness of fit once instead of in three separate instances and of making clear at once, if the fit is bad which part of the data is responsible for it. The generation means were influenced by three parameters: m, the mid-parent value; [d], the additive components and [h], the dominance components in a generalized inverse matrix equation ($M = J^{-1}S$). It estimates the weighted least squared value of m, [d] and [h] from the generation means. The weights are the reciprocals of the variance of the generation means (1/Vx). Expected generation means are then calculated using the weighted m, [d] and [h] values. The comparison between the observed and expected can be effected by assuming the sum of squares minimized in the fitting process to be distributed as X^2 (Chi square) with the degree of freedom equal to the number of generation means (P_1, P_2, F_1, F_2, BC_1 and BC_2) minus the number of parameters which has been fitted (m, [d] and [h]).

Table 1. Determination of A, B, C scaling value, standard error and calculated t value

Scaling test	Value for deviation from zero	Standard Error	t – Cal.
A	2B1 – F1 – P1 = 0 = A	SEA = √VA VA = 4VB1 + VF1 + VP1	t_A = A/SEA
B	2B2 – F1 – P2 = 0 = B	SEB = √VB VB = 4VB1 + VF1 + VP2	t_B = B/SEB
C	4F2 - 2F1 – P1 – P2 = 0 = C	SEC = √VC VC = 16VF2 + 4VF1 + VP1 + VP2	t_C = C/SEC

Inadequacy of the additive-dominance model was tested utilizing one or more of the individual scaling test (A, B and C) showing a significant departure from zero, and by a significant X^2, inadequacy of the additive-dominance model indicates the expression of complex genetic factors (non-allelic interaction or epistasis, linkage and multiplication effects) are present in the inheritance of the trait (Mather and Jinks, 1982). A log transformation is however used to normalize the distribution in the non-segregating populations (Mather and Jinks, 1982).

Table 2. Significance estimates and interpretation of the 3 genetic parameters

Parameters	Gene effects	Interpretation
M	Common genes and the environment	Common genes the parents share are significant if m is significant from zero.
[d]	Additive genes	Additive gene effect is significant if [d] is significant from zero.
[h]	Dominance gene	Dominance gene effect is significant, significant net directional dominance if [h] is significant from zero. Sign of [h] tells the direction of dominance for the trait.

3. Results and discussions

3.1. Pod and seed characters

Analysis of variance indicated significant differences ($p < 0.05$) for dry pod weight per plant, seed weight per plant, and pod width. Significant differences ($p < 0.01$) were recorded for 100 seed weight, pod length, seed length, seed width and seed size (Table 3).

Mean values of hybrids (F_1) of Oboshie x Jenkaah cross and their reciprocals were higher than their respective mid-parents for all traits, while mean values of Oboshie x Nkosour (direct) cross were higher than their corresponding mid-parents for all traits except pod width (Table 3). Among the hybrids, Oboshie x Nkosour cross recorded highest mean values of 26.4, 86.4, 33.30, 17.99, 9.92 and 1.82 for dry pod weight per plant, 100 seeds weight, pod length, seed length, seed width and seed size respectively.

Segregating population (F_2) mean values for both direct crosses (i.e. Oboshie x Nkosour and Oboshie x Jenkaah) were higher than their corresponding mid-parent values except seed size for Oboshie x Jenkaah cross (Table 3). Backcross one (BC_1) values of reciprocal crosses were higher than values of their corresponding direct crosses for all traits except seed width for (Nkosour x Oboshie) x Oboshie and seed size for (Jenkaah x Oboshie) x Oboshie crosses (Table 3).

There was no significance difference between the direct, reciprocals and back crosses, pooled values were computed to estimate the genetic control of seed size and seed weight per plant in two crosses.

3.2. Genetic control for seed size and seed weight per plant

3.2.1. Generation mean analysis of seed size

The generation means and their standard errors, variances, variances of means, weights (reciprocal of variance of generation mean) and expected generation means for seed size in six generations of two crosses (Oboshie x Jenkaah and Oboshie x Nkosour) are presented in Table 4. The estimate of gene effect as per additive-dominance model with their standard errors, degree of freedom and chi square values for the scaling and joint scaling tests for seed size are reported in Tables 5.

The result of the scaling tests of Mather (1949) showed no significant difference from zero at $P = 0.05$ (Table 5) for seed size in scaling test A, B and C in both crosses (Oboshie x Jenkaah and Oboshie x Nkosour). Value for scaling test B and C in both crosses were negative whilst values for scaling test A in both crosses were positive.

Result for the joint scaling tests of Cavalli (1952) showed that values of calculated chi square in both crosses were not significantly different from zero at $P = 0.05$ (Table 5), which clearly indicates an adequacy for the additive dominance model. Both net additive [d] and dominance [h] effects were positive for the two crosses, but the magnitude of [h] in both crosses were higher than that of [d]. The net dominance [h] effect was however not significant at $P \geq 0.05$ (Table 5) in both crosses.

Table 3. Mean pod weight, weight of seed per plant, 100 seed weight, shelling percentage, pod length, pod width, seed length, seed width, seed length and width ratio for the crosses Oboshie x Nkosour and Oboshie x Jenkaah and their reciprocals

Parents/crosses (Generation)	Dry pods weight per plant (g)	Weight of seeds per plant (g)	100 seeds weight (g)	Pod length (mm)	Pod width (mm)	Seed length (mm)	Seed width (mm)	L:W seed (Seed size)
Parents								
Oboshie (Obo)	22.3	14.73	86.9	34.20	12.05	18.08	9.87	1.83
Nkosour (Nko)	24.0	15.43	59.8	29.09	11.11	14.88	9.07	1.64
Jenkaah (Jen)	15.6	9.50	55.3	27.13	10.49	14.74	8.79	1.68
F1 generation								
Nko x Obo (F1)	19.5	13.00	82.9	32.89	11.43	17.80	9.78	1.82
Obo x Nko (F1)	26.4	17.07	86.4	33.30	11.52	17.99	9.92	1.82
Jen x Obo (F1)	24.7	15.57	81.3	33.18	11.89	17.29	9.80	1.76
Obo x Jen (F1)	27.2	17.23	75.6	32.54	11.46	16.85	9.59	1.76
F2 generation								
Nko x Obo (F2)	23.4	15.17	74.0	31.73	11.34	16.99	9.33	1.83
Obo x Nko (F2)	36.0	23.40	82.5	32.23	11.77	17.55	10.18	1.73
Jen x Obo (F2)	22.0	13.77	70.4	30.50	10.83	16.21	9.32	1.74
Obo x Jen (F2)	26.3	17.53	81.1	31.11	11.61	17.23	10.06	1.71
Backcross 1								
(Obo x Nko) x Obo	14.9	9.43	64.5	30.95	11.77	15.85	8.96	1.77
(Nko x Obo) x Obo	24.1	14.83	68.3	31.50	11.90	17.24	8.84	1.95
(Obo x Jen) x Obo	11.3	7.33	66.4	31.69	11.79	16.44	8.88	1.85
(Jen x Obo) x Obo	23.3	15.40	75.7	32.71	12.46	17.18	9.65	1.78
Backcross 2								
(Obo x Nko) x Nko	6.5	4.07	50.4 50.9	27.46	10.65	13.78	8.58	1.61
(Nko x Obo) x Nko	8.0	5.03	51.2	28.50	10.40	14.80	8.32	1.78
(Obo x Jen) x Jen	9.8	5.67	62.4	27.47	11.01	14.39	8.45	1.70
(Jen x Obo) x Jen	18.6	11.17		28.72	11.72	15.36	9.28	1.66
Mean	20.2	12.91	69.8	30.89	11.43	16.35	9.30	1.76
Lsd	14.89*	9.99*	15.36**	2.41**	0.90*	1.20**	0.89**	0.15**
CV (%)	44.5	46.7	13.3	4.7	4.8	4.4	5.8	5.2

**---Significant at P < 0.05 **---Significant at P < 0.01*
ns—Not significant at P < 0.05

Table 4. Estimates of six generation means based on three parameters (m, [d], [h]) for seed size in the crosses between Oboshie x Jenkaah and Oboshie x Nkosour

Generation	No. of plants	Mean (x) ± SE	Variance (V)	Variance of mean (V_x)	Wt ($1/V_x$)	M	D	h	Expected mean
		OBOSHIE X JENKAAH							
Oboshie	10	1.78 ± 0.151	0.023	0.002	434.48	1	1	0	1.80
Jenkaah	10	1.58 ± 0.258	0.066	0.007	151.52	1	-1	0	1.50
F_1	20	1.81 ± 0.166	0.028	0.001	714.25	1	0	1	1.82
F_2	60	1.73 ± 0.195	0.038	0.001	1578.95	1	0	0.5	1.75
B_1	60	1.82 ± 0.180	0.032	0.001	1875.00	1	0.5	0.5	1.81
B_2	60	1.69 ± 0.215	0.046	0.001	1304.35	1	-0.5	0.5	1.69
		OBOSHIE X NKOSOUR							
Oboshie	10	1.78 ± 0.151	0.023	0.002	434.48	1	1	0	1.82
Nkosour	10	1.68 ±0.133	0.018	0.002	555.56	1	-1	0	1.62
F_1	20	1.90 ± 0.285	0.081	0.004	246.91	1	0	1	1.85
F_2	60	1.79 ± 0.202	0.041	0.001	1463.41	1	0	0.5	1.74
B_1	60	1.87 ± 0.239	0.057	0.001	1052.63	1	0.5	0.5	1.84
B_2	60	1.70 ± 0.181	0.033	0.001	1818.18	1	-0.5	0.5	1.74

Mid – parent value for Oboshie x Jenkaah cross = 1.68
Mid- parent value for Oboshie x Nkosour cross = 1.73

The F_1 values, that is, 1.81 and 1.91 for Oboshie x Jenkaah and Oboshie x Nkosour crosses respectively were higher than their corresponding higher parent (Oboshie) and mid-parental values (Table 4). The highest generation mean for seed size in the two crosses was recorded for B_1 (progeny of cross between F_1 and higher parent) in Oboshie x Jenkaah cross (1.82) and F_1 in Oboshie x Nkosour cross (1.90). Jenkaah (parent) and Nkosour (parent) recorded the least mean values for seed size in both crosses.

3.2.2. Generation mean analysis of seed weight per plant

The generation means and their standard errors, variances, variances of means, weights (reciprocal of variance of generation mean) and expected generation means for seed weight per plant in six generations of two crosses (Oboshie x Jenkaah and Oboshie x Nkosour) are presented in Tables 6. The estimate of gene

effect as per additive-dominance model with their standard errors, degree of freedom and chi square values for the scaling and joint scaling tests for seed size are reported in Tables 7.

Table 5. Estimates of scaling and joint scaling test for seed size in two groundnut crosses

	Df	Oboshie x Jenkaah	Df	Oboshie x Nkosour
Scaling test				
A	87	$0.63^{ns} \pm 0.076$	87	$0.60^{ns} \pm 0.100$
B	87	$-0.10^{ns} \pm 0.105$	87	$-2.00^{ns} \pm 0.089$
C	96	$-0.38^{ns} \pm 0.158$	96	$-0.56^{ns} \pm 0.177$
Parameters		**Joint scaling test**		
M	3	1.68** ± 0.032	3	1.72** ± 0.029
[d]	3	0.12* ± 0.028	3	0.10* ± 0.025
[h]	3	$0.14^{ns} \pm 0.057$	3	$0.12^{ns} \pm 0.059$
X^2		1.02^{ns}		6.87^{ns}

**---- Significant at P = 0.05*
***---Significant at P = 0.01*
ns---Not significant at P = 0.05

The highest mean seed weight per plant was recorded for Oboshie (19.58) and lowest for Jenkaah (4.78) in Oboshie x Jenkaah cross, but their hybrid seed weight value (12.05) was lower than their mid-parent value (12.18). Segregation generation (F_2) mean seed weight per plant value (13.82) was higher than corresponding hybrid (12.05), backcross 1 (11.37) and backcross 2 (9.33) in Oboshie x Jenkaah cross (Table 6). Hybrids mean seed weight per plant (14.22) for Oboshie x Nkosour cross was higher than its mid-parent mean value (12.68). F_2 segregating generation mean value (18.87) was higher than it corresponding hybrid and backcrosses (Table 6).

Result of the scaling test of Mather (1949) showed that scaling test A, B and C were not significantly different from zero at P = 0.05 for the cross between Oboshie and Jenkaah, however the value for scaling test A was negative, while that for scaling test B and C were positive (Table 7). The joint scaling test of Cavalli (1952) estimated a non significant Chi-square value for Oboshie x Jenkaah cross at P = 0.05 indicating that the additive- dominance model was adequate for the trait (Table 4.9). The mid-parent value m and net additive [d] were significantly at P = 0.05 and the net dominance effect [h] was not significant at P = 0.05.

Both net additive [d] and dominance [h] effects were positive, but the magnitude of [d] was greater than [h] (Table 7).

Table 6. Estimates of six generation means based on three parameters (m, [d], [h]) for seed weight per plant in the crosses between Oboshie x Jenkaah and Oboshie x Nkosour

Generation	No. of plants	Mean (x) ± SE	Variance (V)	Variance of mean(V_x)	Wt ($1/V_x$)	M	D	H	Expected mean
OBOSHIE X JENKAAH									
Oboshie	5	19.58 ± 3.992	19.92	3.98	0.25	1	1	0	18.30
Jenkaah	5	4.78 ± 3.435	11.80	2.36	0.42	1	-1	0	5.53
F_1	10	12.05 ± 9.582	91.82	9.18	0.11	1	0	1	12.03
F_2	30	13.82 ± 8.885	78.94	2.63	0.38	1	0	0.5	11.97
BC_1	30	11.37 ±10.596	112.27	3.74	0.27	1	0.5	0.5	15.17
BC_2	27	9.33 ± 6.953	48.34	1.79	0.56	1	-0.5	0.5	8.78
OBOSHIE X NKOSOUR									
Oboshie	5	19.58 ± 3.992	19.92	3.98	0.25	1	1	0	19.49
Nkosour	5	5.78 ±2.224	4.95	0.99	1.10	1	-1	0	4.98
F_1	10	14.22 ± 8.080	65.29	6.53	0.15	1	0	1	9.43
F_2	30	18.87 ± 9.109	82.97	2.77	0.36	1	0	0.5	10.83
BC_1	30	10.91 ±6.939	48.15	1.61	0.62	1	0.5	0.5	14.46
BC_2	28	5.07 ± 4.682	21.92	0.78	1.28	1	-0.5	0.5	7.21

Mid parent value for Oboshie x Jenkaah (seed weight per plant) = 12.18
Mid parent value for Oboshie x Nkosour (seed weight per plant) = 12.68

For the Oboshie x Nkosour cross for seed weight, results of Mather's (1949) scaling test showed that scaling test A, B and C were significantly different from zero at P = 0.05. Values for scaling test A and B were negative, while C was positive (Table 7).

Chi-square estimate of the Cavalli (1952) joint scaling test for the cross Oboshie x Nkosour was significantly different from zero at P = 0.05 (Table 7). The mid-parent value m and net additive effect [d] were significant at P = 0.01 and the net dominance effect was not significant at P = 0.05. The net additive effect [d] value was positive and [h] negative. The magnitude of the additive effect was greater than the dominance effect (Table 7).

Since all of the scaling test of Mather (1949) and the joint scaling test of Cavalli (1952) were significant in the cross Oboshie x Nkosour for seed weight, a log transformation of the original data was done to remove the multiplicative effects of genes. The generation mean analysis procedure was repeated using the log-transformed data (Table 8).

After log transformation of original data, Mather (1949) scaling test B and C were significantly different from zero at P = 0.01. Values for scaling Test C was positive while those for A and B were negative. The joint scaling test of Cavalli (1952) estimated a Chi square that was significantly different from zero at P = 0.01. The mid-parent value (m) and net additive effect, [d] were significantly different from zero at P = 0.01 while the net dominance effect was not significantly differ from zero at P = 0.05 (Table 9). Values for parameters m, [d] and [h] were positive and the magnitude of the net additive effect [d] was greater than the net dominance effect [h]. The significance of both scaling test indicated that the additive-dominance model is not adequate for the trait

Table7. Estimates of scaling and joint scaling test for seed weight per plant in two groundnut crosses

	Df	Oboshie x Jenkaah	Df	Oboshie x Nkosour
Scaling test				
A	42	$-1.75^{ns} \pm 5.304$	42	$-2.91^{**} \pm 4.117$
B	39	$0.42^{ns} \pm 4.324$	40	$-3.02^{**} \pm 3.262$
C	46	$0.74^{ns} \pm 9.229$	46	$2.50^{*} \pm 8.684$
Parameters		**Joint scaling test**		
M	3	$10.31^{**} \pm 1.229$	3	$12.24^{**} \pm 0.988$
[d]	3	$5.46^{*} \pm 1.135$	3	$7.25^{**} \pm 0.897$
[h]	3	$4.20^{ns} \pm 2.609$	3	$-2.81^{ns} \pm 2.037$
X^2		5.96^{ns}		41.19^{**}

**---Significant at P = 0.05 **--Significant at P = 0.01*
ns—Not significant at P = 0.05 X^2 = Calculated Chi square

3.3. Chemical composition

Protein content ranged from 26.07 % for the cross Jenkaah x Oboshie (F_1) to 31.20 % for Oboshie (parent) on a dry weight basis. Among the crosses, backcross 1 (B_1) in both direct and reciprocal crosses recorded the

highest protein content ranging from 28.05 % for (Obo x Nko) x Obo to 28.33 % for (Obo x Jen) x Obo. Mean protein values for B_1 (Oboshie x Jenkaah) x Oboshie and B_1 (Jenkaah x Oboshie) x Oboshie are higher than the lower parent (Jenkaah) and their mean oil values are lower than the higher mean parent (Jenkaah) value. Oil content ranged from 47.17 % to 51.22 % with Oboshie (parent) and Jenkaah (parent) recording the least and the highest respectively. Carbohydrate content ranged from 16.84% for Nkosour (parent) to 22.41% for Oboshie x Nkosour (F_1), and ash content on a dry weight basis ranged from 3.64% to 4.19% with Oboshie (parent) and Oboshie x Nkosour (F_2) recording the least and highest respectively.

Table 8. Estimate of six generation means based on three parameter model (m, [d], [h]) for seed weight per plant in the cross between Oboshie x Nkosour (Log transformed)

Generation	No. of plants	Mean (x) ± SE	Variance (V)	Variance of mean (V_x)	Wt ($1/V_x$)	M	D	H	Expected mean
		OBOSHIE X NKOSOUR							
Oboshie	5	1.28 ± 0.105	0.0109	0.0022	458.72	1	1	0	1.27
Nkosour	5	0.73 ± 0.180	0.0323	0.0065	154.80	1	-1	0	0.74
F_1	10	1.09 ± 0.253	0.0641	0.0064	156.01	1	0	1	1.08
F_2	30	1.23 ± 0.219	0.0481	0.0016	623.70	1	0	0.5	1.04
B_1	30	0.93 ±0.335	0.1121	0.0037	267.62	1	0.5	0.5	1.18
B_2	27	0.52 ± 0.452	0.2045	0.0073	136.92	1	-0.5	0.5	0.91

Mid-parent value for Oboshie x Nkosour-Log (seed weight per plant) = 1.01

Table 9. Estimates of scaling and joint scaling test for seed weight per plant in the cross Oboshie x Nkosour (Log transformed)

	Parameters		
Scaling test	A	B	C
	-1.28^{ns} ± 0.397	-3.80** ± 0.205	2.98** ±0.245
Df	42	40	46
Joint scaling test	M	[d]	[h]
	1.01** ± 0.042	0.26** ± 0.042	0.07^{ns} ± 0.083
Df	3	3	3
X^2	58.89**		

***---Significant at P = 0.01 ns---Not significant at P = 0.05*

Table 10. Means and standard errors of protein (%), oil (%), carbohydrate (%) and ash content for proximate composition of 19 generations of parents, direct and reciprocal crosses in groundnut

Generation	Protein (%)	Oil (%)	Carbohydrate (%)	Ash (%)
Parents				
Oboshie (Obo)	31.20 ± 0.248	47.17 ± 0.078	17.99 ± 0.307	3.64 ± 0.050
Nkosour (Nko)	28 61 ± 0.121	47.56 ± 0.010	19.84 ± 0.128	3.96 ± 0.029
Jenkaah (Jen)	27.81 ± 0.127	51.22 ± 0.010	16.84 ± 0.127	4.13 ± 0.050
F1 generation				
Obo x Nko	26.67 ± 0.127	47.21 ± 0.032	22.41 ± 0.085	3.72 ± 0.126
Nko x Obo	26.86 ± 0.121	47.24 ± 0.006	22.14 ± 0.191	3.75 ± 0.145
Obo x Jen	26 43 ± 0.127	48.85 ± 0.006	20.85 ± 0.140	3.87 ± 0.076
Jen x Obo	26.07 ± 0.127	48.79 ± 0.010	21.44 ± 0.272	3.70 ± 0.145
F2 generation				
Obo x Nko	27.33 ± 0.127	47.28 ± 0.006	21.20 ± 0.182	4.19 ± 0.071
Nko x Obo	27.47 ± 0.00	47.28 ± 0.006	21.10 ± 0.140	4.16 ± 0.145
Obo x Jen	26.51 ± 1.097	48.84 ± 0.010	19.93 ± 0.156	4.05 ± 0.100
Jen x Obo	26.97 ± 0.127	48.82 ± 0.006	20.21 ± 0.221	4.00 ± 0.100
Backcross 1				
(Obo x Nko) x Obo	28.05 ± 0.121	47.23 ± 0.006	20.68 ± 0.182	4.05 ± 0.076
(Nko x Obo) x Obo	28.10 ± 0.000	47.20 ± 0.010	20.67 ± 0.067	4.03 ± 0.076
(Obo x Jen) x Obo	28.33 ± 0.000	49.10 ± 0.010	18.80 ± 0.120	3.77 ± 0.121
(Jen x Obo) x Obo	28.18 ± 0.121	49.15 ± 0.010	18.96 ± 0.058	3.71 ± 0.095
Backcross 2				
(Obo x Nko) x Nko	27.81 ± 0.127	47.69 ±0.010	20.54 ± 0.184	3.97 ± 0.076
(Nko x Obo) x Nko	27.67 ± 0.000	47.70 ± 0.006	20.65 ± 0.026	3.98 ± 0.029
(Obo x Jen) x Jen	27.90 ± 0.000	49.25 ± 0.006	19.12 ± 0.095	3.74 ± 0.098
(Jen x Obo) x Jen	27.99 ± 0.121	49.35 ± 0.006	18.49 ± 0.207	4.17 ± 0.098

Values are means of triplicate determination expressed on dry weight basis

4. Discussion

There were indication of the (F_2) segregating generations to inherit bolded seed trait, since their 100-seeds weight were higher than 60g, which is in conformity with confectionery varieties (Ramanatha Rao and Murty, 1994). Composite analysis mean values for protein and oil contents ranged from 26.07 to 31.20% and from 47.17 to 51.22% respectively. This was in agreement with (Dwivedi et al., 1993; Jambunathan et al., 1985; Asibou et al., 2008; Wang et al., 2011). Mean values of protein content for direct and reciprocal of (Oboshie x Jenkaah) x Oboshie and (Jenkaah x Oboshie) x Oboshie backcrosses were higher than lower parent (Jenkaah), and their corresponding oil contents were lower than the higher mean parent (Jenkaah) for the trait. This was in agreement with earlier report of Dwivedi et al. (1990), who recorded negative correlation between

protein and oil. This is a common trend of confectionery groundnut varieties, increased protein content and decreased oil content.

Among measured traits, it was observed that no significant differences occurred between direct and reciprocal crosses to account for maternal effect in this study. Mean of direct and reciprocals were pooled to develop a six generation mean using a three parameter component additive-dominance model to investigate the gene effects of seed size and seed weight in two groundnut crosses.

Seed size is an important trait for quality purpose. Large-seeded varieties are likely to attract premium price in the world market of edible nuts. The fact that values obtained for seed size of F_1 for Oboshie x Jenkaah and Oboshie x Nkosour crosses were higher than those in the two parents indicated dominance towards parent with larger seed size, and further implies heterosis for larger seed size. This is in agreement with the work of Balaiah et al. (1977) and Layrisse et al. (1980).

Results of Mather's (1949) scaling and Cavalli's (1952) joint scaling tests showed that neither A, B and C scale was significant for t-test nor the Chi-square (X^2) value was significant, indicating seed size for Oboshie x Jenkaah and Oboshie x Nkosour crosses fitted well to the additive-dominance model.

The additive-dominance model indicated that the additive gene contributed significantly to the inheritance of larger seed size in the two crosses. This was in contrast with the report of Hariprasanna et al., (2006) that seed size was controlled by non-additive gene action. According to Venuprasad et al. (2011) significance of additive effects suggests that effective selection could be practised in early generation. The magnitude of the net dominance effect, [h] was higher than the net additive effect but was not significant at $P \geq 0.05$. The positive signs of the dominance effects indicated dominance in the direction of the higher parent for seed size trait.

The mean seed weight of F_1 for Oboshie x Jenkaah cross was lower than it mid-parent value, this implies dominance towards lower seed weight per plant. Results of Mather (1949) and Cavalli, (1952) scaling and joint scaling tests for seed weight per plant revealed that both A, B and C scaling and Chi-square values were not significantly different from zero at $P = 0.05$ for Oboshie x Jenkaah cross, indicating adequacy for the additive-dominance model. Jayalakshmi et al. (2003) also reported adequacy of additive-dominance model to explain variation in kernel yield (seed weight) in groundnut.

The additive-dominance model revealed that net additive effect contributed significantly to the inheritance of seed weight per plant in the Oboshie x Jenkaah cross. This is in agreement with the findings of Naazar Ali et al. (1999) that only additive gene effects were important for seed weight in groundnut. Various workers revealed predominant additive gene action for seed traits (Garet, 1976; Mohammed et al., 1978; Layrisse et al., 1980; Swe and Branch, 1986; Anderson et al., 1993). The net dominance effect, [h] was not significant for Oboshie x Jenkaah cross, and the magnitude of the net additive effect, [d] was higher than the net dominance effect, [h]. The positive sign of the net dominance value indicated dominance in the direction of the higher parent for seed weight per plant.

In the generation mean analysis for seed weight per plant in the Oboshie x Nkosour cross, Mather's (1949) A and B scaling test were highly significant and C was significantly different from zero. Cavalli's (1952) joint scaling test was significantly different from zero indicating the inadequacy of the additive-dominance model

in explaining its mode of inheritance. This indicated that the generation mean do not depend solely upon the additive and dominance effects of the genes, suggesting non allelic (epistasis) to be the major influence in the determination of the trait.

To remove the interaction, a log transformation suggested by Mather and Jinks (1982) was used to normalize the data for the purpose of adequacy but yielded a Chi-square value that was significantly different from zero. Notwithstanding, the mean seed weight per plant value of F_1 was higher than the mid-parent value indicating dominance towards parent with heavier seed. Besides joint scaling test (Cavalli, 1952), scaling test (Mather, 1949) A, B and C showed that simple additive-dominance model was not suitable for seed weight per plant in Oboshie x Nkosour cross. Alake et al. (2012) had similar experience in their work on West African okra.

5. Conclusion and recommendations

The present study showed that genetic recombination for seed quality traits will be achieved through hybridization. The mean values for most quantitative traits measured for F_2 generations were higher than their corresponding lower parents or intermediate between the two parents. Generation mean analysis showed traits were highly influenced by environmental variation.

The study showed that the additive-dominance model was adequate to explain the mode of inheritance of seed size in both crosses. The net additive effect contributed significantly to the inheritance of seed size; therefore, suggesting that selection for improvement of seed size could be accomplished in the F_2 generation in both crosses.

The additive-dominance model was inadequate to explain the mode of inheritance of seed weight per plant for Oboshie x Nkosour cross. Therefore genetic improvement of seed weight (yield) per plant will be easier through indirect selection for a component trait such as seed size than through direct selection for seed weight itself. This selection criterion is suggested because of character association between seed weight and seed size as observed by Chiow and Wynne (1983). Pure line breeding with selection at early generation is suggested for improvement of both traits studied, because the net additive genetic effect contributed significantly in controlling the inheritance of both seed size and seed weight per plant.

Since the simple additive-dominance model was inadequate to explain the mode of inheritance of seed weight per plant in Oboshie x Nkosour cross, the model should be extended to a six parameter model indicating three interaction terms [i], [j] and [l] using the methodology of Jinks and Jones (1958) in which net additive [d], dominance [h], additive x additive [i], additive x dominance [j] and dominance x dominance [l] effects will be calculated.

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