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Genetic variability and heritability estimates of some properties of groundnut (*Arachis hypogaea* L.) kernels

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Abstract

Knowledge of physical and mechanical properties of groundnut is essential for the design of equipment for the processing, transportation, cleaning, sorting, separation and packaging. The present study was undertaken at Dang, in the soudano-guinea zone of Cameroon, to investigate varietal differences for seed weight, geometric surface, porosity, degree of sphericity, hydration capacity and angle of repose of the kernels in 12 groundnut (Arachis hypogaea L.) genotypes, estimate their heritability values through simple analysis of variance, and evaluate the correlations among these parameters. The experimental design was a randomized complete block with six replicates. Analysis of variance revealed that these genotypes presented a significant variability ($P \leq 0.05$) for the six physical properties. The average properties of kernels were found to be a hundred seed mass of 20.46g, a surface area of 0.84 cm2, a sphericity of 35.50%, and a porosity of 0.65, a hydration capacity of 0.42 g /seed and an angle of repose of 33.35°. These parameters were moderately to highly heritable with broad-sense heritability (h2) values ranged from 0.58 (hydration capacity) to 0.98 (seed weight). Expected genetic advance was from 4.76 to 53.52 %. Seed weight was positively correlated with surface area, degree of sphericity and porosity while the angle of repose was negatively correlated with seed weight and hydration capacity. The results of this study showed that these physical properties can be improved genetically.

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Introduction

Groundnut (*Arachis hypogaea* L.) also known as peanut or earthnut, is regarded as one of the most important protein-rich and it occupies the fifth position as oilseed crop after soybean, cottonseed, rape seed, and sunflower seed (Nath and Alam, 2002; Davies, 2009). *A. hypogaea* is grown on about 24.6 million hectares of land in tropical regions and the warmer areas of temperate regions of the world, with an annual global production of about 38.2 million tons (Liu *et al.*, 2009). The nuts are harvested and then crushed to remove the kernels that provide a major source of digestible protein, cooking oil, and a significant source of animal feed and important raw materials for many industrials products (Dwivedi *et al.*, 1990; Kale *et al.*, 1998; Aydin, 2007). They are also eaten raw, boiled, fried and roasted. In most homes, women use the kernels paste in soups and stews as thickener (Nath and Alam, 2002). The production of groundnut oil, and its by-products, raw and fried cake is an important source of income for women in African countries (Dwivedi *et al.*, 1990). Despite the economic potential of groundnut kernel as good source of oil and a valuable export product, little is known about the physical properties of seeds (Knauft and Wynne, 1995). Only limited studies have been done on the physical properties of groundnut kernels (Olajide and Igbeka, 2003; Aydin, 2007; Davies, 2009; Firouzi *et al.*, 2009). The processing operations, predominantly done manually, are time consuming, unsanitary and laborious (Olajide and Igbeka, 2003; Liu *et al.*, 2009).

Knowledge of the physical properties of *A. hypogaea* kernels is necessary for the design of equipment for mechanical oil extraction, transporting, sorting, cleaning, separating, smashing and processing of agricultural products (Davies, 2009; Liu *et al.*, 2009). Presently, the equipments used in the processing of groundnut have been generally design without taken into cognizant the physical properties of seeds (Olajide and Igbeka, 2003; Razari *et al.*, 2007). These properties affect the conveying characteristics of solid materials by air or water and cooling and heating loads of food materials (Moshenin, 1970; Ozarslan, 2002; Thakur and Gupta, 2006). Categorization of kernel sizes plays a significant role in processing and also aids equipment design (Olajide and Igbeka, 2003). The volume and density of the seeds have an important role in numerous technological processes and in the evaluation of product quality (Singh and Goswami, 1996; Tabatabaeefa, 2003). Therefore, to produce seed of a specific size, and to meet a specific market demand, a better understanding of the inheritance pattern and gene interactions that govern physical traits is required along with an understanding of potential environmental influence. Many studies have reported on the physical properties of grains or seeds of plants, such as bambara groundnuts (Baryeh, 2001), chickpea (Konak *et al.*, 2002; Hossain *et al.*, 2010), cotton (Ozarslan, 2002), cowpea (Kabas *et al.*, 2007; Noubissié *et al.*, 2011), cumin (Singh and Goswami, 1996), dry beans (Ceyhan, 2006), pea (Yalcin *et al.*, 2007), pistachio nut (Razari *et al.*, 2007), rice (Thakur and Gupta, 2006), safflower (Baumler *et al.*, 2006), sesame (Adebowale *et al.*, 2011; Azeez and Morakinyo, 2011), soybean (Deshpande *et al.*, 1993), vetch (Yalcin and Ozarslan, 2004) and wheat (Tabatabaeefa, 2003).

The information on the heritability of seeds physical characteristics and correlations among these traits will be profitable for planning suitable breeding strategies (Ceylan, 2006; Azeez and Morakinyo, 2011). However, research on the genetics of these properties is limited until now and there are no known reports on the heritability of these properties and the relationships among them (Aydin, 2007; Liu *et al.*, 2009). Peanut is a self-fertilizing species, and varieties normally consist of a single homozygous line (Knauft and Wynne, 1995; Liu *et al.*, 2009). A single method commonly used to estimate trait heritability in peanut is to measure phenotypic variance among F_2 individuals developed from cross between two inbred lines (Knauft and Wynne, 1995; Nath and Alam, 2002). This type of analysis has a narrow inference space because it highly depends on the genetic differences between the two particular inbred lines selected (Lynch and Walsh, 1998; Xu *et al.*, 2009). Therefore, heritability estimated from the cross of two inbred lines cannot be generalized to other populations or line crosses. A method to estimate the broad-sense heritability with larger inference space and that do not require hybridization and population development steps can be conducted by analyzing lines for trait performance using simple analysis of variance (Rahman *et al.*, 2005; Xu *et al.*, 2009).

Therefore, the present study has been undertaken to investigate in twelve groundnut genotypes grown in Cameroon, the extent of available genetic variation for six physical properties of kernels, namely seed weight, surface area, sphericity, porosity, hydration capacity and angle of repose; assess through simple analysis of variance their magnitude of heritability in broad-sense; estimate the amount of genetic gain expected to occur during selection program and evaluate the correlations among these parameters; so that the quality of the kernels can be genetically improved.

Materials and methods

The research was carried out during 2010 to 2011 at the University of Ngaoundéré campus (1113 m altitude, 7.28°N latitude and 13.34°E longitude), which is located at Dang, a village of Ngaoundéré in the Adamawa region, Cameroon. This region belongs to the high altitude Guinea savannah ecological zone (Noubissié *et al.*, 2011). The climate is characterized by two seasons: a rainy season (April – October) and a dry season (November – March). The annual rainfall is about 1500 mm. The mean annual temperature is 22°C, while the annual humidity is about 70%. The soil is ferruginous type, developed on basalt, with 9.4 mg kg^{-1} organic matter, ratio C/N=0.33 and pH 5.2.

Twelve groundnut varieties obtained from the Institute of Agricultural Research for Development (IRAD Maroua, Cameroon) were used for the study (Table 1).

A field trial was conducted during the 2011 growing season. The seeds of the entries were sown in a randomized complete block design (RCBD) with six replications. Sowing took place on April 17, 2011, on an experimental surface of 300 m^2 (25.0 m length x 12 m broad). Each plot unit consisted on one row of 3 m length x 0.5 m broad, spaced 40 cm apart. Two seeds of each variety were sown at an intra-row spacing of 40 cm and thinned to one per hill, 20 days after sowing (DAS). The plots were manually weeded at 20 DAS, 40 DAS and at 60 DAS. A maturity, harvesting was done, when the pods were ready for picking. The fruits were cleaned in an air screen cleaner to remove all foreign matter. Kernels were separated from pods after drying and their initial moisture content was determined. A known sample was weighed into a previously weighed moisture cup and dried in an oven at 60°C for 12 h to a constant weight and moisture content calculated as follows (Yalcin and Ozarslan, 2004; Baumler *et al.*, 2006; Razari *et al.*, 2007):

Moisture (%) = [(weight of sample before drying - weight of sample after drying) / sample weight] x 100.

Moisture content was found to vary between 7.33 and 9.48% d.b. (Table 1). The 100-seed mass was measured by using an electronic balance of 0.001g sensitivity (Sartorius Prodilab, France).

The sphericity and the surface area of groundnut kernels were calculated according to Mohsenin (1970) and Baryeh (2001). For each replication, 40 seeds were selected at random per genotype and their individual length (*L*), width (*W*) and thickness (*T*) were measured from three main dimensions which are in three perpendicular directions using a micrometer gauge reading to 0.01 mm (Junior Chrome Mat Roch / France). The average diameter of seed was calculated by using the geometric mean (D_g) of the three axial dimensions by using the following relationship (Ozarslan, 2002; Olajide and Igbeka, 2003):

$D_g = (LWT)^{1/3}$

Where L, W and T are length, width and thickness of groundnuts, respectively.

The surface area S (cm^2) of groundnut seeds was found by analogy with a sphere of same geometric mean diameter, using the equation below (Moshenin, 1970):

$$S = \pi . . D_g^2 \quad (cm^2)$$

According to Moshenin (1970) and Baryeh (2001), the degree of sphericity (φ) of seeds was estimated following relationship:

$$\varphi = D_g / L$$

The percentage porosity (φ) which is the fraction of the space in the bulk seeds which is not occupied by the grains was determined as follows (Deshpande *et al.*, 1993):

$$\varepsilon = 100 \left[(1 - \rho_b) / \rho_f \right] \ (\%)$$

Where, ρb is the bulk density in g $ml^{-1}$and ρ_f is the seed density in g ml^{-1}.

Seed true density (ρ_f) was measured by the liquid displacement method using sample of 25 seeds (Mohsenin, 1970, Yalcin and Ozarslan, 2004). The volume of liquid displaced was found by immersing weighed seeds in the toluene (C7H8).The bulk density ρ_b was determined according to the standard test weight procedure by filling a container of 500 ml with the seeds from the height of 150 mm at a constant rate and then weighing the content (Baryeh, 2001). Kernel hydration capacity (HC) was calculated as percentage using the following formula (Thakur and Gupta, 2006; Malik *et al.*, 2011):

HC = (Wf – W0)/100

Where Wf, is the weight of 100 seeds soaked for 24h and Wo is the weight of 100 seeds without soaking.

Angle of repose was determined using a pelexi glass box of 300 x 300 x 300 mm^3, having a removable front panel (Olajide and Igbeka, 2003). The box was filled with sample and then the front panel was quickly removed, allowing the seeds to flow and assume a natural slope. The angle of repose was calculated from the measurement of the depth of free surface of the sample at the center (Olajide and Igbeka, 2003; Firouzi *et al.*, 2009). It is equal to arctangent of the coefficient of static friction between the surfaces.

For each variety, the physical properties were studied in six replicates. Data of the 12 pure lines were subjected to analysis of variance (ANOVA) using computer program STATGRAPHICS PLUS version 3.0. The genotypic means were compared using Least Significant Difference at 5% level of probability (LSD 5%).

Heritability in broad sense (h^2) was measured as the ratio of genetic variance of homozygous parents (σ^2_g) in the phenotypic variance between parents (σ^2_p) (Xu *et al.*, 2009).

$$h^2 = \sigma^2_g / \sigma^2_p = (\sigma^2_p - \sigma^2_E) / \sigma^2_p$$

Where, σ^2_p = the total phenotypic (inter-varietal) variance obtained from the twelve varieties; σ^2_E = the environmental (intra-varietal) variance is estimated by the average of the phenotypic variance among plants of each parental line; σ^2_g = genetic variance derived from the difference between the phenotypic variance and the environmental variance. The heritability was estimated on mean basis from the average of the total genetic variance and on varietal basis using the genetic variance calculated from each of the twelve cultivars. Expected genetic advance (GA) of the genotypes as per cent of mean was calculated using the following formula given by Allard (1960):

$$GA (\%) = [K \times (\sigma^2_p)^{1/2} \times h^2] / M$$

Where, K = the selection differential in standard units and it was 1.75 at 10% level of selection (Allard, 1960); $(\sigma^2_p)^{1/2}$ = standard deviation of the phenotypic variance, h^2 = the heritability value in broad-sense and M = mean of the population.

Correlation coefficient (r) was used to determine the degree of association between different parameters. Correlation coefficient was computed at phenotypic levels between pairs of characters adopting the Pearson's formula (Singh and Chaudhary, 1985).

Results

Analysis of variance indicated significant differences between the genotypes (P≤0.05) for all the investigated characteristics (Table 2). The values of 100-seed weight (mean = 53.51g) ranged from 39.44 to 90.50g with *V. Local* being the heaviest while *55-437* was the lightest. The geometric surface of kernel (mean = 3.44cm²) ranged from 2.65 (*K3237-80*) to 5.22cm² (*V. Local*). The degree of porosity (mean = 50.35%) was varied from 43.26 (*M51377-I*) to 59.08% (*V. Local*). Results indicated that the sphericity of the kernel (mean = 0.70) ranged from 0.67 (*CGS1272)* to 0.75 and kernels of varieties *V. Local* and *ICGV86003* showed the higher values for this trait. The hydration capacity (mean = 0.42 g/seed) varied from 0.24 (*V. Ouest*) to 0.66 g/seed (*GH119-20*) while for the angle of repose, the mean value was 33.35° with range of 27.63 (*V. Local*) to 38.05° (*28-206*). The coefficient of variability (CV) was high for seed weight (30.59%) and geometric surface (24.12%); moderate for hydration capacity (14.29%), porosity (10.45%) and angle of repose (10.28%), and low for the degree of sphericity (4.28%).

Table 1. Description of groundnut genotypes used in the study

Genotypes	Date	Type of cultivars	Cycle (days)	Growing area in Cameroon	Moisture content (%)
CGS 269	1990	Intermediate	90-100	Northern regions	8.10 ± 0.64
CGS 1272	1990	Intermediate	100	Northern regions	9.04 ± 0.45
GH119-20	1960	Virginia jumbo	110	Center, East	8.66 ± 0.26
ICGV 86003	2003	Spanish	120	Northern regions	8.55 ± 0.52
K1332-78	1980	Virginia	120	Center, South	7.80 ± 0.33
K3237-80	1980	Viginia	90-100	Northern regions	9.00 ± 0.15
M 513 77-I	1980	Virginia	120	Center, East	7.77 ± 0.44
RMP 91	1990	Virginia	140	Southern regions	9.48 ± 0.65
28-206	1950	Viginia	120	Southern regions	8.90 ± 0.09
55-437	1960	Spanish	90	North, Center	9.22 ± 0.68
V. Ouest	1950	Spanish	105	Western regions	7.33 ± 0.44
V. Local	1950	Viginia	115	Adamaoua	8.86 ± 0.29

Date: Date of diffusion in Cameroon

The estimation of genetic parameters like genotypic (σ^2_g) and environmental (σ^2_E) variance, broad-sense heritability (h^2) and genetic advance (GA) of *A. hypgaea* varieties under study is given in Table 3. High heritability estimates combined with high genetic advance as per cent of mean was noted for seed weight (h^2 = 0.98; GA = 53.52%) and geometric surface (h^2 = 0.83; GA = 35.17%). Moderate to high heritability coupled with low genetic gain as per cent of mean was recorded for degree of sphericity (h^2 = 0.71; GA = 5.71%) and hydration capacity (h^2 = 0.58; GA = 4.76%). High heritability with moderate genetic gain was observed for porosity (h^2 = 0.82; GA = 14.82%) and angle of repose (h^2 = 0.64; GA = 11.51%).

The interrelationships among the various physical traits of groundnut are given in Table 4. Seed weight showed positive and significant correlation with geometric surface (r = 0.98), degree of sphericity (r = 0.68) and porosity of the seed (r = 0.62). Significant and positive correlation was also noted between seed surface and sphericity (r = 0.63), porosity and surface area (r = 0.62), sphericity and porosity (r = 0.71), sphericity and hydration capacity of seed (r = 0.61). Non significant but positive correlation was recorded for seed weight and hydration capacity (r = 0.44), seed surface and hydration capacity (r = 0.46). In contrast, the angle of repose was negatively correlated with seed weight (r = -0.86) and hydration capacity (r = -0.58). Negative but not significant correlation was noted between angle of repose and sphericity (r = -0.39), angle of repose and porosity (r = -0.36), hydration capacity and porosity (r = -0.17).

Table 2. Mean performance and analysis of variance for physical properties of kernels in 12 groundnut genotypes

Genotypes	100 seed weight (g)	Seed surface (cm^2)	Porosity (%)	Degree of sphericity	Hydration capacity (g/seed)	Angle of repose (degree)
CGS 269	48.62^{c}	3.30^{c}	47.98^{de}	0.68^{c}	0.38^{cd}	30.96^{ef}
CGS 1272	41.00^{de}	3.06^{c}	47.07^{def}	$0,67^{c}$	0.44^{c}	36.00^{abc}
GH119-20	76.53^{b}	4.74^{ab}	54.41^{bc}	$0,71^{abc}$	0.66^{a}	28.11^{g}
ICGV 86003	70.21^{b}	4.21^{b}	54.05^{bc}	$0,75^{a}$	0.33^{de}	29.64^{fg}
K13 32-78	47.43^{cd}	3.14^{c}	43.42^{f}	$0,69^{bc}$	0.57^{b}	33.21^{cde}
K32 37-80	43.32^{cde}	2.65^{c}	43.92^{ef}	$0,67^{c}$	0.55^{b}	35.22^{bc}
M 513 77-I	47.71^{cd}	3.18^{c}	43.26^{f}	$0,69^{bc}$	0.41^{c}	34.21^{cd}
RMP 91	48.85^{c}	3.19^{c}	53.23^{bc}	$0,69^{bc}$	0.38^{cd}	32.10^{def}
28-206	40.78^{e}	2.90^{c}	56.05^{ab}	$0,70^{bc}$	0.29^{ef}	38.05^{a}
55-437	39.44^{e}	2.71^{c}	50.89^{cd}	$0,73^{ab}$	0.25^{f}	37.30^{ab}
V. Ouest	47.90^{c}	2.95^{c}	50.86^{cd}	$0,71^{abc}$	0.24^{f}	37.88^{ab}
V. Local	90.50^{a}	5.22^{a}	59.08^{a}	$0,75^{a}$	0.52^{b}	27.63^{g}
LSD (5%)	6.88	0.65	4.26	0.04	0.07	2.80
CV (%)	30.59	24.12	10.45	4.28	14.29	10.28

LSD: Least significant difference at P=0.05; CV: Coefficient of variation; Means in the same column followed by different letters are significantly different at P≤0.05

Table 3. Genetic analysis of kernels physical properties in 12 groundnut genotypes.

Characteristics	Mean	SE	σ_E^2	σ_g^2	h^2	h^2 range	GA %
Seed weight (g)	53.51	16.37	27.47	238.46	0.98 ± 0.01	0.96-0.99	53.52
Surface (cm^2)	3.44	0.83	0.18	0.50	0.83 ± 0.18	0.39-0.95	35.17
Porosity (%)	50.35	5.26	5.75	21.87	0.81 ± 0.09	0.64-0.93	14.82
Sphericity	0.70	0.03	0.00023	0.00056	0.71 ± 0.14	0.53-0.87	5.71
Hydration(g/seed)	0.42	0.06	0.0015	0.0021	0.58 ± 0.11	0.38-0.84	4.76
Angle of repose (°)	33.35	3.43	4.18	7.58	0.64 ± 0.09	0.51-0.86	11.51

SE: Standard error; σ_E^2: Environmental variance; σ_g^2: Genetic variance; h^2: heritability in broad-sense, GA: Genetic advance at 10% intensity of selection

Table 4. Estimates of correlation coefficient among six seed physical traits in 12 groundnut varieties.

Characteristics	100 seed weight	Geometric surface	Degree of sphericity	Porosity	Hydration capacity
100 seed weight	1				
Geometric surface	0.98**	1			
Degree of sphericity	0.68**	0.63*	1		
Porosity	0.62*	0.62*	0.71**	1	
Hydration capacity	0.44ns	0.46ns	0.61*	-0.17ns	1
Angle of repose	-0.86**	-0.87**	-0.39ns	-0.36ns	-0.58*

**: Significant at P≤0.01; *: Significant at P≤0.05; ns: Non-significant at P≥0.05

Discussion

Significant differences amongst the twelve groundnut pure lines for kernel physical properties indicated the presence of diversity in the material growing in Cameroon. Variability for physical properties was also reported in groundnut by Kale et al. (1998); Nath and Alam (2002) and Firouzi *et al.* (2009). In other cultivated crops like Bambara groundnut (Baryeh, 2001); common bean (Ceylan, 2006); chickpea (Malik *et al.*, 2011); cowpea (Kabas *et al.*, 2007; Noubissié *et al.*, 2011) pea (Yalcin *et al.*, 2007), and in sesame (Adebowale *et al.*, 2011; Azeez and Morakinyo, 2011), significant differences were noted among varieties for the physical characteristics of the seeds. When the physical properties values obtained in this research were compared with those of previous studies (Olajide and Igbeka, 2003; Aydin, 2007), they were in most cases within normal limits. Studying groundnut kernels from Bayselsa market (Nigeria) at moisture content of 7.6% dry basis, Davies (2009) noted that the average 100 grain mass, sphericity, surface area, porosity and angle of repose were 37.6g, 0.69, 1.21 cm^2, 36.4% and 28°. Geometric surface which is dependent on length, breadth and thickness, is very important in determination of heat and mass transfer (Adebowale *et al.*, 2011). Physical dimensions (length, breadth and thickness) are useful in determining aperture size in grain handling machinery. The average kernel sphericity was 0.70, and this is lower than corresponding value of 0.76 reported by Olajide and Igbeka (2003) but higher than the values of 51.6 – 57.1 obtained by Aydin (2007). The degree of sphericity is indicative of the seed shapes toward a sphere. Sphericity is one of the most important properties because it affects how easily grains can be processed by the food industry (Kabas *et al.*, 2001). The size of the kernels is one of the most important trade attribute for export of hand-picked selected (HPS) groundnut (Aydin, 2007). A minimum of 44 g for 100 seeds is essential for a sample to its grading as HPS. The hydration capacity is associated with physical entrainment and the hydrophilic properties of molecules. Since groundnut kernels are also eaten on a volume basis, a sample characterized by high hydration capacity could be nutrient-deficient because much of volume consumed is comprised of water. In contrast, processors benefit from groundnuts with relatively high hydration capacity because of greater unit output. The values of angle of repose obtained in this study are considerably higher than those reported by Olajide and Igbeka (2003) in Nigeria on reddish skin variety, at moisture content of 4.6%. This may be due to the relative smoothness of the surface of the kernels. The angle of repose of a granular material is the steepest angle of descent or dip of the slope relative to the horizontal plane when material on the slope face is on the verge of sliding.

The distribution of values of these physical properties for the tested population appeared to be continuous and suggested a quantitative inheritance for these traits (Singh and Chaudhary, 1985). The coefficient of variability provides a measure to compare genetic variability present in various quantitative characters (Lynch and Walsh, 1998). The higher values recorded for seed weight and seed area clearly indicated large degree of genotypic variability in these traits. The success of breeder in selecting suitable quality parameters lies largely on existence and exploitation of genetic variability to the fullest extent (Allard, 1960). High values of coefficient of variability suggest better improvement scope for these traits by selection (Singh and Chaudhary, 1985). Seed physical properties are genetically controlled but the implementation of the program is affected by the environmental factors in particular moisture content and temperature (Tabatabaeefa, 2003; Rahman *et al*., 2005; Baumler *et al*., 2006; Razari *et al*., 2007; Yalcin, 2007; Firouzi *et al*., 2009). Aydin (2007) and Firouzi *et al.* (2009) evaluated physical properties of *A. hypogaea* kernel as a function of moisture content varying from 5 to 35% (wb) and observed that porosity, true density, projected area, terminal velocity, coefficient of friction and the angle of repose increase with increase in moisture content. In this moisture range, the angle of repose increased from 30.3 to 37.95° alongside with porosity of kernel which increased from 40 to 50%.

In general, the genetic variance was higher in magnitude than the environmental variance for all the characters studied, suggesting that the environment had little effect in those characters expression. Genotypic and phenotypic variances make available the information of variability only but the heritable portion of this variation is determined by the estimation of heritability (Singh and Chaudhary, 1985). The effective selection for traits under improvement depends on sufficient genetic variation of these characters and their heritability values. Broad sense heritability values were high (0.58- 0.98) suggesting that the largest part of the observed variation of these physical properties was genetic in nature. High heritability estimates signify the effectiveness of these characters through selection for crop improvement (Hossain *et al*., 2010). In our study, the seed weight showed highest heritability together with high genetic advance. Malik *et al.* (2011) observed the same trends in chickpea lines for 100 seed weight (0.996) and hydration capacity (0.667). Rahman *et al.* (2005) also recorded high heritability values for seed weight and surface area in cotton. Conversely, in mutant genotypes of *Dianthus caryophyllus*, Roychowdhury and Tah (2011) recorded poor values for heritability ($h^2 = 0.42$) and genetic advance estimates (GA = 5.97%) for seed weight. The knowledge on heritability of traits is helpful to decide the selection procedure to be followed to improve the trait in a situation (Singh and Chaudhary, 1985). Therefore, the possibility of obtaining a satisfactory selection gain is evident.

Higher estimates heritability with genetic as per cent of mean was observed for seed weight and seed surface indicating the presence of additive gene action and so selection can be easily done for these traits (Singh and Chaudhary, 1985; Hossain *et al*., 2010). This indicates the lesser influence of environment in the expression of these characters and prevalence of additive gene action in their inheritance, hence amenable for simple selection (Roychowdhury and Tah, 2011). This result is crucial for breeding programs because additive variance, which depends only on the contribution from homozygotes, can be fixed by selection, and is the most important component in gain prediction expressions (Allard, 1960). Rahman *et al.* (2005) noted that temperature had a relatively stronger effect on the inheritance pattern of seed weight and seed surface area in cotton. When an additive allelic interaction is predominant, selection is facilitated, because superior individuals will produce superior descent. In cowpea, Noubissié *et al.* (2011) concluded through diallel analysis that the seed weight, porosity and seed area were controlled mainly by additive genes. The traits like the degree of sphericity and the hydration capacity which expressed relatively high value heritability and low genetic gain showed non additive gene interaction; hence heterosis breeding would be recommended for these parameters (Roychowdhury and Tah, 2011). Importance of non additive genes for the degree of sphericity was pointed out also in cowpea by Noubissié *et al.* (2011). However, as outlined by Allard (1960), and Nath and Alam (2002), since peanut is a self-pollinated plant, the expected genetic advance from the narrow sense heritability is more accurate as compared with that estimated from the broad sense heritability.

As outlined by Knauft and Wynne (1995), seed size (weight and volume) is an important attribute that determine the consumer preference in groundnut cultivars. Kernel weight had positive and significant correlations with geometric surface, degree of sphericity and porosity of the seeds. Dwivedi *et al.* (1990) and Kale *et al.* (1998) reported the positive association between seed mass and oil content but a negative relationship for seed weight and protein content in groundnut. In chickpea, Malik *et al.* (2011) found strong and positive correlation between seed size and hydration capacity. Our results showed that hydration capacity exhibited positive but insignificant correlation with seed weight. Azeez and Morakinyo (2011) observed that in sesame, positive and significant correlations were noted between seed weight and seed surface area (r = 0.862), seed sphericity and seed surface area (r = 0.779) but a positive and non significant relationship was recorded for seed sphericity and seed weight (r = 0.581). Selection based on big kernels will increase seed surface, porosity, sphericity and oil content but decrease the angle of repose and the protein content. As reported by Hossain *et al.* (2010) in chickpea, identification of molecular markers based on seed weight in groundnut might be fruitful for progress in selection.

Conclusion

The results of this investigation suggested that physical properties of kernels in groundnut are determined by architecture of cultivars and environmental factors. Variations among genotypes have been shown to be heritable; however the efficacy of selection depends on knowledge of the genetic control of the measured traits. Selection based on seed surface area, degree of sphericity, porosity and hydration capacity may be more efficient for suitable groundnut genotype screening for seed weight. These findings can be used to design processing and handling machines for groundnut kernels and to plan crosses in order to improve these physical properties. Improved methods to predict genetic gain and evaluate these quantitative traits without the environmental influence are also needed.

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