

Variance Components, Heritability and Character Correlations in Genotypes of *Arachis Hypogaea* L. (Groundnut)

Makinde, Sunday C.O.; *Osundinakin, Michael I.; Ani, Abosede O.; Ojewumi, Anthony W.; Onyemeka, Regland M.; Olokooba, Rachael O. and Esan, Oyekunle O.

Department of Botany, Faculty of Science, Lagos State University Ojo, P.O. Box 0001, LASU Post Office, Ojo, Lagos, Nigeria.

* Corresponding Author: michael.osundinakin@lasu.edu.ng; michael2lead@yahoo.com.

Abstract

This study aimed at characterizing the genotypic and phenotypic parameters of *Arachis hypogaea* in different planting seasons. Seeds of twenty-two lines of *A. hypogaea* obtained from both ICRISAT India and locally, were planted in two different planting seasons (Environments) in the Botanical Garden, Lagos State University. Planting was done on ridges using Randomized Complete Block Design (RCBD) with three replications. Results revealed higher phenotypic coefficient of variation than genotypic coefficient of variation for all characters studied. The phenotypic data showed that yield per plant had a significant positive correlation with number of pods per plant (0.67, 0.71) and final plant height (0.29, 0.34) in both environments. It was also significant and positively correlated with number of branches per plant (0.31) in environment 1 (E1) and with stem girth at maturity (0.43) in environment 1 (E2). Genotypic correlation coefficients exhibited similarity in both the magnitude and direction compared to phenotypic correlation coefficients. All the characters studied showed non-significant genotypic correlations with yield, except number of pods per plant that showed positive significant correlations (E1= 0.65, E2= 0.64) with yield in both environments. The environmental correlation exhibited similarity in both environments at different levels of significance. Environmental correlations of yield per plant were highly significant and positive with number of pods per plant (E1= 0.95, E2= 0.96) in the two environments. The path analysis of yield showed that number of pods per plant had the highest positive direct correlation, coupled with high positive genotypic correlation; implying a measure of yield in groundnut.

Keywords: Correlation, Path analysis, Genotype, Environment and Phenotype

Introduction

Groundnut (*Arachis hypogaea* L.), a member of the Papilionaceae subfamily which belongs to family Fabaceae (Sharma *et al.* 2017). Groundnuts are currently cultivated in the world's tropical, sub-tropical, and warm temperate climates, with Brazil in South America as the principal place of origin (Radhamani and Singh 2008, Semba *et al.* 2021). It is the thirteenth most important food crop of the world, the fourth most important source of edible oil and the third most important source of vegetable protein (Encyclopedia of Agricultural Science, 1994). Groundnut seeds contain high quality edible oil (50 %), as well as easily digestible protein (25 %) and 20 % carbohydrate. It also contains minerals such as phosphorus, calcium, zinc, and vitamins such as A, C, E, K, thiamine and niacin (Gummadala *et al.* 2022). Groundnut is an important cash crop of the Nigerian semi-arid region, and it reached the peak of its production in Nigeria between the years 1967 – 1971, when approximately 1.7 million tons of pods were produced from an area of 1.8 million hectares (Agboola, 1979). There has been a drastic decline in its production in recent years due to unfavourable weather or climatic conditions, reduced labour availability and outbreak of rosette disease epidemics. In the 1960s groundnut was a major source of Nigeria's foreign exchange earnings (Agboola, 1979). About ₦38 million was realized annually from the export of the crop between 1963 and 1973. Out of about 22 million hectares devoted to the cultivation of groundnut genotypes worldwide, Nigeria is responsible for 1.4 million hectares (Agunbiade, 1986). Subsequently, the decline in the cultivation of groundnut genotypes has been largely attributed to the discovery of mineral oil and outbreak of rosette epidemic of 1975 (Olufade, 1986).

Genotype is determined by the genetic information contained in the entire DNA content of the genome (Begna, 2021). Accordingly, an insight into the magnitude of variability present in the gene pool of a crop species is of utmost importance to a plant breeder for starting a judicious plant-breeding program. In earlier years, visual observations used to be the measurement of variability in a plant population. Now biometrical methods are available for systematic assessment of variability (Pasipanodya *et al.* 2022). The phenotypic expression of the plant characters is mainly controlled by the genetic combination of the plant and the environment in which it is growing. In addition, the genetic variance of any quantitative trait is composed of additive variance (heritable) and non-additive variance, and includes dominance and epistasis (non-allelic interaction) (Kumar *et al.* 2017). It is necessary to separate the total variation into heritable and non-heritable components with the help of genetic parameters i.e. genotypic and phenotypic coefficient of variation, heritability and genetic gain (Kahrizi *et al.* 2010).

Genetic diversity is the occurrence of genetic variation in an entire species and can be assessed by examining differences in the DNA sequence in a population of individuals (Haun *et al.*, 2011). It is the vital element of all variety development programs, and its existence in crop germplasm aids the efficient selection of high yielding, better adapted crop plants with

possible uses of such variety in crossing scheme of breeders for variety development programs. The performance of selection largely depends upon the value of genetic variability present in the plant population (Begna, 2021). The large amount of variability present in any genetic material indicates the scope for further improvement of the crop (Baig *et al.* 2018). Evidence now abounds to show that a great deal of genetic variation and diverse genetic bases necessary for creating further genetic variability exist in groundnut. The combination of genetic progress and heritability estimates elucidates the form of character that can be improved by selection (Alake, 2018, Aswini *et al.* 2023). The knowledge of genetic variability existing in the different parameters contributing to yield is an important criterion for yield enhancement but in highly self-pollinated crops like groundnut. Furthermore, information on the nature of associations between yield and its component characters and their direct and indirect contributions on pod yield is necessary for efficient selection.

Phenotypic characterization is the first step for describing, assessing, and classifying germplasm collections to ascertain their use in groundnut breeding (Garba *et al.* 2015). The assessment of the phenotypes has proven effective for diversity analysis in some legumes and oil crops, including groundnut (Garba *et al.* 2015). Multivariate analysis is a popular method for estimating genetic variability to study the components of variation and their genetic relationships between germplasm collections. Multivariate analyses have been used in many studies on groundnuts, and its selection effectiveness depends on the extent of genetic variability present in the available germplasm for the trait of interest and its heritability value (Garba *et al.* 2015). Heritability measures the relative importance of genetic and non-genetic factors in the expression of phenotypic differences among genotypes in a population. It also estimates the expected response to selection and chose the best breeding approach to improve the target trait(s). Therefore, this study aimed to determine the variance component, heritability estimates, and the correlation between selected morphological traits related to yield in some groundnut genotypes in two different environments. The specific objectives are to (i) determine the variation existing among groundnut genotypes, (ii) determine heritability and relationship between some characters in groundnut, (iii) recommend desirable groundnut genotypes for cultivation in the study environments.

Materials and methods

Planting materials

Breeder seeds of twenty-two varieties of groundnut (*Arachis hypogaea*, L.) were collected from International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru 502 324, Andra Pradesh, India. In addition, seven varieties were collected locally from three (3) different states in Nigeria (Table 1).

Agronomic practices

The plantings were carried out in two different planting seasons (Environments). Plantings was in the Department of Botany nursery, Lagos State University, Ojo Campus, Lagos (6° 36'N, 3° 34'E) Lagos State, Nigeria. First planting was done on the 12th April, 2021(rain-fed; E1) while the second was on the 19th of October 2022 (irrigated; E2). Land preparation was done manually, using hoes to make ridges. Thus, the planting was on a raised surface. Two to three seeds of each genotype were sown in double row plots, arranged in a Randomized Complete Block Design (RCBD) with three replicates.

Each row contained ten stands spaced 40 cm apart. An inter-row spacing of 1 m was maintained (1 m x 4 m plot size). Each stand was thinned to one plant at two weeks after planting. Manual weeding was done at regular intervals to ensure minimal crop-weeds competition. There was no application of inorganic fertilizers and chemicals (herbicides and pesticides) throughout the plantings.

Table 1: Code names and source/ origin of groundnut genotypes

Number	Genotype	source/origin
1	ICG – 4998	ICRISAT India
2	ICG – 862	„
3	ICG – 6402	„
4	ICG – 8490	„
5	ICG – 4412	„
6	ICG – 156	„
7	ICG – 14466	„
8	ICG – 12370	„
9	ICG – 2106	„
10	ICG – 4343	„

11	ICG – 12189	„
12	ICG – 442	„
13	ICG – 4598	„
14	ICG – 7000	„
15	ICG – 1399	„
16	ICGY-6M- 5236	Zaria, Nigeria
17	ICG-IS- 11687	„
18	ICGY-5M- 4746	„
19	ICG-IS- 6646	Unilorin, Nigeria
20	ICG- IS- 3584	„
21	ICG49- 85A	UNAAB, Nigeria
22	UGA-7- M	„

Measurement of quantitative traits

Agronomic and yield data were collected on each genotype. Ten competitive plants were sampled in each plot. At maturity, pods were harvested on plant basis and data were collected on eleven (11) characters following IBPGR/ ICRISAT Groundnut Descriptors (1981) (Table 2).

Table 2: Characters studied and their methods of measurement/scoring

S/No	Character	Measurement / Score (s)
1	Days to 50% flowering	Estimated using calendar
2	Plant height at flowering	Measured (cm)
3	Number of leaves/plant at flowering	Counted
4	Final plant height	Measured (cm)
5	Days to maturity	Estimated using calendar
6	Number of branches/ plant at maturity	Counted
7	Nodes on the main stem/plant at maturity	Counted
8	Number of pods/ plant	Counted
9	Stem girth/plant at maturity	Measured (cm)
10	Weight of 100 seeds (100 seeds)	Measured (g)
11	Yield/ plant	Measured (g)

Statistical analysis

Mean values of the characters were computed for the ten sampled plants in each plot. The means were subjected to analysis of variance and covariance using SAS 2000 (Table 3). Data collected on the studied characters from First planting (12th April, 2021(rain-fed; E1)) and the second planting (irrigated; E2) were used to calculate variances and covariances which were used to obtain the phenotypic, genotypic and environmental correlations as described below;

$$\text{Phenotypic correlation, } r_p = (\sigma_{gxy} + \sigma_{cxy}) / [(\sigma_{gx}^2 + \sigma_{cx}^2)(\sigma_{gy}^2 + \sigma_{cy}^2)]^{1/2}$$

$$\text{Genotypic correlation, } r_g = \sigma_{gxy} / (\sigma_{gx}^2 \times \sigma_{gy}^2)^{1/2}$$

$$\text{Environmental correlation, } r_e = \sigma_{cxy} / (\sigma_{cx}^2 \times \sigma_{cy}^2)^{1/2}$$

$$\text{Heritability estimate } h^2_B = (\sigma_{gx}^2 / \sigma_{gx}^2 + \sigma_{cx}^2) \times 100$$

Where;

σ_{gx}^2 and σ_{gy}^2 are the genotypic variances of characters x and y respectively;

σ_{cx}^2 and σ_{cy}^2 are the environmental variances for characters x and y and σ_{gxy} and σ_{cxy} are the genotypic and environmental covariance of character x and y respectively.

A path analysis was carried out to determine the direct and indirect effects of some characters on pod yield following the procedure outlined by Dewey and Lu (1959).

Results

Genotypic and phenotypic coefficient of variability for the eleven studied characters

Genotypic coefficient of variability (CV) was generally higher than phenotypic CV (Table 4). The characters exhibited a wide and continuous variation across varieties. All the studied characters exhibited different ranges for the two environments. Genotypic and phenotypic coefficients of variation were generally low except, for plant height, number of leaves per plant, final plant height, number of pods per plant and yield per plant in the first environment. Low genotypic and phenotypic CV's were also recorded for all characters except number of pods per plant in the second environment.

Broad sense heritability of the studied characters

Estimates ranged between 62.34 % and 90.67 % in the first environment, between 24.75 % and 89.46 % in the second environment for “number of branches per plant at flowering” and “days to 50 % flowering” respectively (Table 4). In the first environment, heritability estimate was moderately high for “number of branches per plant at flowering” (62.34 %). It was high for “days to 50 % flowering” (73.10 %), “number of nodes on the main stem at maturity” (78.46), and very high estimates which is above 80 % for the remaining parameters. In the second environment, low heritability estimate was recorded for “number of branches per plant at flowering” (24.75 %), high estimates were observed for “stem girth at maturity” (79.45 %), and “yield per plant (74.43 %). Very high heritability estimates (above 80 %) were recorded for the remaining studied characters.

Table 3: Mean values of agronomic and yield characters measured in 22 groundnut genotypes grown in two environments

Genotypes	Days to 50 % flowering	Plant height at flowering (cm)	Number of leaves flowering	Days to maturity	Final plant height (cm)	Number of branches/ plant at flowering	Nodes on the main stem at maturity	Stem girth at maturity (cm)	Number of pods/ plant	Sample weight (100g)
ICG – 4998	27.60 ^a	20.10 ^h	31.89 ⁿ	123.80 ^j	45.21 ^h	4.67 ^{fg}	27.67 ⁱ	2.26 ^a	170.65 ^e	41.45 ^h
ICG – 862	26.20 ^a	17.75 ^k	76.99 ^a	117.00 ^o	37.78 ^j	4.84 ^{ef}	29.41 ^{sh}	1.65 ^k	95.85 ^j	40.40 ⁱ
ICG – 6402	28.60 ^a	15.06 ^m	62.28 ^c	120.40 ^k	46.28 ^h	4.67 ^{fg}	34.79 ^b	1.98 ^{ef}	91.64 ^{jk}	27.01 ^q
ICG – 8490	28.60 ^f	22.47 ^c	33.72 ^l	125.80 ⁱ	49.76 ^f	4.61 ^{gh}	28.77 ^{hi}	2.12 ^{bc}	93.99 ^j	50.06 ^d
ICG – 4412	32.20 ^e	20.87 ^a	56.33 ^a	133.20 ^c	39.51 ⁱ	4.89 ^{de}	25.95 ^l	1.81 ^{hi}	87.29 ^{kl}	30.75 ^o
ICG – 156	26.20 ^m	19.21 ⁱ	71.42 ^c	129.80 ^b	33.55 ^k	4.63 ^{gh}	24.92 ^j	1.71 ^{jk}	62.32 ^o	62.84 ^b
ICG – 14466	31.20 ^e	20.96 ^a	41.57 ⁱ	131.40 ^g	48.75 ^{fg}	4.45 ^h	29.43 ^{sh}	1.80 ^{hi}	78.99 ^{mn}	42.98 ^g
ICG – 12370	28.40 ^b	19.01 ^{ji}	68.08 ^d	118.60 ^l	40.43 ⁱ	5.08 ^{cd}	29.87 ^{sh}	1.87 ^{sh}	184.20 ^b	30.57 ^o
ICG – 2106	24.80 ^f	21.49 ^f	30.53 ^{no}	107.80 ^u	62.59 ^c	4.92 ^{cde}	33.40 ^e	1.99 ^c	190.45 ^a	40.10 ^{ji}
ICG – 4343	26.60 ^l	20.27 ^h	57.84 ^f	117.40 ^m	49.36 ^f	4.95 ^{cde}	30.13 ^{efg}	1.90 ^{fg}	131.36 ^g	37.93 ^k
ICG – 12189	25.80 ^a	21.76 ^f	29.91 ^{op}	134.20 ^d	55.21 ^d	5.61 ^a	32.32 ^{cd}	2.17 ^b	115.45 ^h	53.26 ^c
ICG – 442	25.40 ^a	21.65 ^f	33.08 ^{lm}	116.00 ^q	70.11 ^b	4.96 ^{cde}	35.19 ^b	2.20 ^{ab}	141.30 ^f	34.28 ^m
ICG – 4598	33.40 ^b	23.15 ^d	73.05 ^b	132.40 ^f	55.80 ^d	4.95 ^{cde}	30.60 ^{efg}	2.19 ^{ab}	173.64 ^c	48.23 ^f
ICG – 7000	31.80 ^d	18.64 ⁱ	67.53 ^d	144.80 ^c	47.61 ^g	5.48 ^{ab}	31.01 ^{ef}	2.08 ^{cd}	83.48 ^{lm}	40.00 ^j
ICG – 1399	23.80 ^a	25.02 ^b	36.39 ^{ji}	150.40 ^b	62.81 ^c	4.85 ^{ef}	33.22 ^c	2.15 ^{bc}	81.52 ^{mn}	30.41 ^o
ICG – 1399	26.80 ^l	19.27 ⁱ	34.63 ^{kl}	116.20 ^p	45.57 ^h	5.05 ^{cd}	28.67 ^{hi}	1.77 ^{ji}	112.76 ^{hi}	29.81 ^p
ICGY-6M- 5236	25.20 ^e	16.83 ^l	28.52 ^p	110.60 ^s	49.84 ^f	5.11 ^c	30.96 ^{ef}	1.90 ^{fg}	109.03 ⁱ	33.24 ⁿ
ICG-IS- 11687	41.60 ^a	21.69 ^f	42.09 ⁱ	159.40 ^a	37.74 ^{ji}	4.95 ^{cde}	26.13 ^l	2.03 ^{de}	57.65 ^p	64.24 ^a
ICGY-5M- 4746	26.60 ^k	23.70 ^c	28.44 ^p	115.80 ^r	74.45 ^a	4.89 ^{de}	33.25 ^c	1.96 ^{ef}	76.72 ⁿ	35.10 ^l
ICG-IS- 6646	25.00 ^a	22.57 ^c	28.89 ^p	117.00 ^o	56.25 ^d	5.36 ^b	31.33 ^{de}	1.75 ^{ji}	156.32 ^d	30.53 ^o
ICG49- 85A	23.80 ^v	23.58 ^{cd}	35.95 ^{jk}	107.60 ^v	56.05 ^d	4.76 ^{efg}	39.28 ^a	2.14 ^{bc}	130.04 ^g	43.01 ^g
UGA-7- M	25.80 ^p	25.96 ^a	44.3 ^{lh}	108.80 ^f	52.75 ^c	4.91 ^{de}	32.99 ^c	2.07 ^{cd}	150.65 ^c	48.93 ^c

a, b,= DMRT values. Means with similar alphabets along the same column are not significantly different (P< 0.05)

Table 4: Genotypic coefficient of variability (gCV), phenotypic coefficient of variability (pCV) and broad sense heritability (h²B) for eleven groundnut traits in two environments

Character	First Environment (Lagos 2021) E1				Second Environment (Lagos 2022) E2			
	Range	Genotypic CV	Phenotypic CV	h ² B (%)	Range	Genotypic CV	Phenotypic CV	h ² B (%)
Days to 50 % flowering	24.00 – 42.00	14.6	14.52	73.10	21.00 – 38.00	15.55	15.38	87.76
Plant height at flowering	7.80 – 25.80	36.58	36.38	82.77	12.00 – 24.00	14.67	14.38	86.32
Number of leaves at flowering	28.00 – 133.00	56.90	55.02	89.78	13.40 – 53.60	28.76	27.96	85.29
Days to maturity	108.00- 160.00	11.16	11.03	90.67	100.00 – 150.00	11.36	11.23	89.46
Final plant height	20.40 – 83.50	39.99	39.67	88.65	29.70 – 81.80	22.53	22.46	87.34
Number of branches at flowering	4.00 – 9.00	21.89	21.01	62.34	4.00 – 5.00	4.94	4.06	24.75
Number of nodes on the main stem at maturity	22.00 – 34.00	12.77	11.56	78.46	24.40 – 44.00	14.73	14.62	89.12
Stem girth at maturity	2.00 – 2.90	10.97	10.20	64.65	1.60 – 2.60	13.54	11.65	79.45
Number of number of pods per plant	60.00 – 241.00	36.66	35.98	89.32	57.40 – 309.80	35.66	34.83	84.56
weight of 100 seeds	26.80 – 65.14	27.21	25.84	90.12	28.10 – 65.00	26.87	25.38	89.23
Yield per plant	11.80 – 50.40	38.58	38.57	89.12	12.60 – 45.00	29.36	29.05	74.43

Character correlations

Phenotypic correlation

The phenotypic correlation coefficients between characters in the two environments are presented in Table 5. “Yield per plant” showed significant positive correlation with “number of pods per plant” (0.67, 0.71) and “final plant height” (0.29, 0.34). It was however, negatively correlated with “days to maturity” (-0.48, -0.39) in both environments. It was significant and positively correlated with “number of branches per plant” (0.31) in the first environment and with “stem girth at maturity” (0.71) in the second environment. “Days to 50 % flowering” showed significant positive correlations with “final plant height” (0.68, 0.64), “weight of 100 seeds” (0.41, 0.48) and “number of leaves at flowering” (0.33), “final plant height” (0.31) in the first environment. However, it correlated negatively with “nodes on the main stem at maturity” (-0.46) in the second environment. “Plant height at flowering” had positive correlation with “days to maturity” (0.30), “final plant height” (0.34) in the first environment and “weight of 100 seeds” in the second environment. The “number of leaves at flowering” showed significant positive correlations with “final plant height” (0.46) and “weight of 100 seeds” (0.31) in the first and second environment respectively, but showed negative correlation with “nodes on the main stem at maturity” (-0.36) in the second. Significant negative correlation was observed between “days to maturity” and “final plant height” (-0.57), “number of branches at flowering” (-0.33), “nodes on the main stem at maturity” (-0.47) in the second environment and “number of pods per plant” (-0.43, -0.42) in both environments. It correlated positively with “weight of 100 seeds” (0.35, 0.32) in both environments. “Final plant height” showed highly significant positive correlation with “number of branches per plant at flowering” (0.35, 0.38) and “number of nodes on the main stem per plant at maturity” (0.47, 0.66). “Number of branches at flowering” showed significant positive correlation with “nodes on the main stem at maturity” (0.40) in the second environment. Highly significant positive correlation was observed between “nodes on the main stem at maturity”, “stem girth at maturity” (0.55), and “number of pods per plant” (0.38) in the second environment. “Stem girth at maturity” had highly significant correlation with “number of pods per plant” only in the second environment.

Table 5: Phenotypic correlation coefficients among eleven characters of groundnut genotypes in two environment

Character	Environment	Height/ plant at flowering	Number of leaves at flowering	Days to maturity	Final plant height	Number of branches at flowering.	Nodes on the main stem at maturity	Stem girth at maturity	Number of pods per plant	Sample Seed Weight	Yield/ plant
Days to 50 % flowering	1	-0.25	0.33*	0.68**	0.31*	-0.11	-0.18	0.10	-0.23	0.41**	0.04
	2	-0.01	0.18	0.64**	0.28	-0.02	-0.46**	0.11	-0.23	0.48**	0.04
Height/ plant at flowering	1		0.04	0.30*	0.34*	-0.19	0.09	0.01	-0.06	0.12	0.26
	2		0.09	0.05	0.05	-0.13	0.14	0.10	-0.12	0.37*	0.13
Number of leaves at flowering	1			0.26	0.46**	0.08	-0.36**	-0.15	0.19	0.08	0.13
	2			0.14	0.08	0.08	-0.09	-0.17	0.11	0.31*	0.16
Days to maturity	1				-0.05	-0.11	-0.24	0.15	-0.43**	0.35**	-0.48**
	2				-0.37*	-0.33*	-0.47**	0.01	-0.42*	0.32*	-0.39**
Final plant height.	1					0.35**	0.47**	0.18	0.11	-0.37**	0.29*
	2					0.38**	0.66**	0.40**	0.23	-0.19	0.34**
Number of branches/ plant at flowering	1						0.21	0.25	0.09	-0.12	0.31*
	2						0.40**	0.07	0.13	-0.02	0.28
Nodes on the main stem at maturity	1							0.24	0.18	0.35*	0.14
	2							0.55**	0.38**	0.24	0.25
Stem girth at maturity	1								-0.09	0.04	0.22
	2								0.54**	0.08	0.43**
Number of pods/ plant	1									-0.27	0.67**
	2									-0.23	0.71**
weight of 100 seeds	1										0.13
	2										0.05

*, ** = Significant at $P \leq 0.05$, $P \leq 0.01$ respective. 1= first environment and 2= second environment

Genotypic correlation

The genotypic correlation coefficients between the characters in the two environments are presented in Table 6. In most cases, characters exhibited similarity in both the magnitude and direction of correlation coefficients compared to phenotypic correlation coefficient. Generally, more characters showed significant phenotypic correlation than the genotypic correlation. All the characters showed non-significant genotypic correlations with yield, except number of “pods per plant” that showed positive significant correlations (0.65, 0.64) in both environments. Significant positive genotypic correlations was observed between “days to 50 % flowering” and “days to maturity” (0.68, 0.64) and “weight of 100 seeds” (0.45, 0.47) in both environments. However, it showed significant negative correlation with “nodes on the main stem at maturity” (-0.47) only in the second environment. “Plant height at flowering” showed non-significant genotypic correlation with all other characters in both environments. “Number of leaves at flowering” did not exhibit a clear-cut correlation direction. It showed positive genotypic correlations with “days to maturity” (0.25, 0.06), “number of branches per plant at flowering” (0.04, 0.22) and “weight of 100 seeds” (0.10, 0.28) in the two environments. Whereas, it showed “negative genotypic correlations” with “number of nodes on the main stem at maturity” (-0.28), “stem girth at maturity” (-0.15), “number of pods per plant” (-0.20) in the first environment, and correlated positively with the same characters (0.03, 0.15 and 0.17 respectively) in the second environment. It equally showed a significant and non-significant inverse genotypic correlations with final plant height (-0.47 and -0.05) in the first and second environment respectively. “Days to maturity” had significant reverse correlation with “nodes on the main stem at maturity” (-0.47) in the first environment and “number of pods per plant” (-0.42, -0.48) in the two environments. “Final plant height” showed positive genotypic correlation with “number of leaves at flowering” (0.44) in the first environment and “nodes on the main stem at maturity” (0.62, 0.71) in both environments. “Number of branches at flowering” showed significant positive genotypic correlation with “nodes on the main stem at maturity” (0.44) only in the first environment. Significant positive genotypic correlation was observed between “nodes on the main stem at maturity” and “stem girth at maturity” (0.43, 0.57) in the two environments. “Stem girth at maturity” showed significant positive genotypic correlation with “number of pods per plant” only in the second environment

Table 6: Genotypic correlation coefficients among eleven characters of groundnut genotypes in two environments

Character	Environment	Height/				Number of branches/ plant at flowering.				Sample Seed Weight	Yield/ plant
		plant at flowering	Number of leaves at flowering	Days to maturity	Final plant height	Nodes on the main stem at maturity	Stem girth at maturity	Number of pods per plant			
Days to 50 % flowering	1	-0.27	0.32	0.68**	-0.31	-0.20	-0.18	-0.10	-0.22	0.45*	-0.05
	2	-0.05	0.14	0.64**	-0.30	0.15	-0.47*	-0.04	-0.26	0.47*	-0.04
Plant height at flowering	1		0.02	0.32	-0.29	-0.19	-0.09	0.04	-0.12	0.04	0.23
	2		0.13	0.12	0.04	-0.11	-0.04	0.10	0.08	0.37	0.08
Number of leaves at flowering	1			0.25	-0.47*	0.04	-0.28	-0.15	-0.20	0.10	0.14
	2			0.06	-0.05	0.22	0.03	0.15	0.17	0.28	0.24
Days to maturity	1				0.04	0.10	-0.05	0.30	-0.42*	0.39	-0.33
	2				-0.37	-0.17	-0.47*	0.10	-0.48*	0.31	-0.41
Final plant height	1					0.44*	0.62**	0.21	0.15	-0.36	-0.26
	2					0.04	0.71**	0.32	0.24	-0.21	-0.36
Number of branches/ plant at flowering	1						0.44*	-0.23	0.09	-0.25	0.35
	2						-0.05	-0.04	-0.01	0.33	0.17
Nodes on the main stem at maturity	1							0.43*	0.11	-0.38	-0.34
	2							0.57**	0.42	-0.26	-0.25
Stem girth at maturity	1								0.24	0.07	0.31
	2								0.45*	0.07	0.20
Number of pods per plant	1									-0.28	0.65**
	2									-0.24	0.64**
weight of 100 seeds	1										0.11
	2										0.12

*, ** =
P ≤ 0.05, P ≤

Significant at
0.01

respectively. 1= first environment and 2= second environment

Environmental Correlation

The environmental correlation coefficients between the characters for the two environments (first and second environments) are presented in Table 7. Except in few cases, characters exhibited similar environmental correlation in both environments though at different levels of significance. Environmental correlations of “yield per plant” were highly significant and positive with “number of pods per plant” (0.95, 0.96) in the two environments, and with “stem girth at maturity” (0.76) only in the second environment. It showed non-significant positive correlations with “plant height at flowering” (0.47, 0.26), “days to maturity” (0.17, 0.03) and “weight of 100 seeds” (0.43 and 0.12) in both environments. Reverse significant environmental correlations were observed between “yield/ plant and number of leaves at flowering” (-0.70, -0.25) and “number of nodes” on the main stem per plant at maturity (-0.54, -0.36) in the first and second environments respectively.

“Days to 50 % flowering” had significant positive environmental correlations with “days to maturity” (0.89, 0.99), “final plant height” (0.94, 0.64), “number of branches at flowering” (0.62, 0.61) in both environments, “plant height at flowering” (0.79) only in the first environment and “number of nodes” on the main stem at maturity (0.55) in the second environment. It however, showed significant reverse environmental correlations with “number of leaves at flowering” (-0.90) only in the first environment. “Plant height at flowering” showed positive environmental correlations with all studied characters. However, it correlated significantly with “days to maturity” (0.58, 0.49) and “weight of 100 seeds” (0.64, 0.68) in both environments, “number of leaves” per plant at flowering (0.60), “final plant height” (0.65), “number of pods” per plant (0.58) only in the first environment and “number of branches” per plant at flowering (0.60) in the second environment. “Number of leaves” at flowering had significant and positive environmental correlations with “number of branches per plant” at maturity (0.69, 0.54) in both environments, “weight of 100 seeds” (0.61) only in the first environment and “number of nodes” on the main stem at maturity (0.54) in the second environment. It had significant but negative environmental correlations with “number of pods” per plant (-0.74) only in the first environment, “days to maturity” (-0.91) and “final plant height” (-0.59) in the second environment. Significant negative environmental correlations were observed between “days to maturity” and “final plant height” (-0.84, -0.64) in both environments and “number of nodes” on the main stem at maturity (-0.58) only in the second environment. “Final plant height” showed significant positive correlations with “nodes on the main stem at maturity” (0.88), “stem girth at maturity” (0.72) and “weight of 100 seeds” (0.56) in the second environment. “Number of branches at flowering” had significant negative correlation with “stem girth at maturity” (-0.66) only in the first environment. “Number of pods per plant” showed strong positive environmental correlation with “stem girth at maturity” (0.44, 0.82) in both environments. Significant positive correlation was observed between “stem girth at maturity” and “number of pods per plant” (0.77) during the second environment.

Table 7: Environmental correlation coefficients among eleven characters of groundnut genotypes in two environments

Character	Environment		Plant height at flowering	Number of leaves at flowering	Days to maturity	Final plant height.	Number of branches at flowering.	Nodes on the main stem at maturity	Stem girth at maturity	Number of pods/ plant	Weight of 100 Seeds	Yield/ plant
	1	2										
Days to 50 % flowering	1		0.79**	-0.09	0.89**	0.94**	0.62*	0.32	-0.22	-0.31	-0.44	-0.24
	2		0.44	-0.90**	0.99**	0.64*	0.61*	0.55*	-0.21	-0.06	0.23	-0.08
Plant height at flowering	1			0.60*	0.58*	0.65**	0.41	0.18	0.02	0.58*	0.64**	0.47
	2			0.30	0.49*	0.08	0.60*	0.41	0.05	0.27	0.68**	0.26
Number of leaves at flowering	1				-0.24	-0.04	0.69**	0.15	-0.21	-0.74**	0.61*	-0.70**
	2				-0.91**	-0.59*	0.54*	0.54*	-0.41	-0.42	0.22	-0.25
Days to maturity	1					-0.84**	0.08	-0.02	-0.07	-0.03	-0.09	0.17
	2					-0.64*	0.62*	-0.58*	-0.25	-0.10	-0.17	0.03
Final plant height	1						0.07	0.47	0.21	-0.12	0.52*	-0.11
	2						0.19	0.88**	0.72**	-0.30	0.56*	-0.26
Number of branches/ plant at flowering	1							-0.28	-0.66**	-0.24	-0.40	-0.13
	2							-0.25	-0.13	-0.14	-0.17	-0.20
Nodes on the main stem at maturity	1								0.44	-0.30	-0.63*	-0.52*
	2								0.82**	-0.37	-0.11	-0.36
Stem girth at maturity	1									0.33	0.08	0.46
	2									0.77**	0.25	0.76**
Number of pods/ plant	1										0.32	0.95**
	2										0.17	0.96**
weight of 100 seeds	1											0.43
	2											0.44

*, ** = Significant at $P \leq 0.05$, $P \leq 0.01$ respectively. 1= first environment and 2= second environment

Direct and indirect effects of characters on yield per plant

In the first environments, “number of pods per plant” had the largest positive direct effect (0.66) on “pod yield” with the highest indirect positive contribution of “days to maturity” (0.68) and a large indirect effect through reduction in “number of leaves at flowering” (-0.46) (Table 8). “Number of branches at flowering” also had a high positive direct effect (0.33) on “pod yield” during the first environment with the highest indirect effect through “nodes on the main stem at maturity” (0.30). However, “days to maturity” and “stem girth” at maturity exhibited negative direct effect on yield in the first environment.

In the second environment “number of pods” per plant also exhibited the largest direct positive effect (0.70) on “yield per plant”. Days to maturity had the largest direct negative effect (-0.36) and largest positive indirect effect (0.68) on “yield per plant”. “Days to maturity” (0.68, 0.64) and sample “seed weight” (0.42, 0.48) had highly significant indirect effect on “yield per plant” in the two environments while, “number of nodes” on the main stem at maturity showed highly significant indirect effect (-0.47) on yield in the second environment with “final plant height” contributing the largest indirect positive effect (0.68). It is note-worthy that “number of pods/ plant” and “days to maturity” had largest direct positive (0.66, 0.70) and negative (-0.33, -0.36) contributions respectively in the two environments. In the same vain, “number of pods” per plant had negative indirect effect and hence, significant genotypic correlations in the two environments. The largest negative direct effect (-0.36) on yield in the second environment was expressed by “days to maturity” and “stem girth per plant at maturity” with “days to 50 % flowering” being an important indirect contributor through “days to maturity”. In the same way, “number of nodes on the main stem” at maturity expressed highly significant indirect effect on “yield per plant” through final plant height. Generally, however, some environmental inconsistencies were observed on the direct contributions to yield for characters such as “days to 50 % flowering” and final height/ plant. The indirect effects of some characters also followed similar trend

Table 8: Direct and indirect effects of some characters on yield in twenty two genotypes of groundnut

Character	Environment	Direct effect on yield/plant	Indirect effect on yield/ plant through											Genotypic correlation
			Days to 50 % flowering	Plant height at flowering	Number of leaves at flowering	Days to maturity	Final plant height	Number of branches at flowering	Nodes on the main stem at maturity	Stem girth at maturity	Number of pods/plant	weight of 100 seeds		
Days to 50 % flowering	1	-0.04	-	-0.25*	0.33**	0.68**	-0.31*	-0.14	-0.20	0.10	-0.23	0.42**	-0.05	
	2	0.04	-	-0.30*	0.17	0.64**	-0.29*	0.03	-0.47**	0.09	-0.24	0.48**	-0.04	
Plant height at flowering	1	0.25*	-0.25	-	0.03	0.11	-0.32*	-0.19	-0.03	0.02	-0.08	0.09	0.23	
	2	0.12	-0.30	-	0.11	0.08	-0.45**	-0.13	-0.03	0.11	-0.11	0.37**	0.08	
Number of leaves at flowering	1	-0.14	0.33**	0.03	-	0.26*	-0.46**	0.06	-0.33**	0.15	-0.19	0.09	0.14	
	2	-0.19	0.17	0.11	-	0.12	-0.07	0.01	-0.06	0.17	-0.13	0.31*	0.24	
Days to maturity	1	-0.33**	0.68**	0.11	0.26*	-	-0.05	0.11	-0.17	0.20	-0.39**	0.37**	-0.33	
	2	-0.36**	0.64**	0.08	0.12	-	-0.37**	0.28*	-0.47**	0.03	-0.44**	0.32*	-0.41	
Final plant height	1	-0.25*	-0.31*	-0.32*	-0.46**	-0.05	-	0.38**	0.52**	0.19	0.12	-0.37**	-0.26	
	2	0.34**	-0.29*	-0.45**	-0.07	-0.37**	-	0.29*	0.68**	0.37**	0.24	-0.20	-0.36	
Number of branches at flowering	1	0.33**	-0.14	-0.19	0.06	0.11	0.38**	-	0.30*	0.24	0.09	-0.16	0.35	
	2	0.24*	0.03	-0.13	0.01	0.28*	0.29*	-	0.27*	0.04	0.10	-0.11	0.17	
Nodes on the main stem at maturity	1	-0.21	-0.20	-0.03	-0.33**	-0.17	0.52**	0.30*	-	0.20	0.15	-0.36**	-0.34	
	2	-0.25*	-0.47**	-0.03	-0.06	-0.47**	0.68**	0.27*	-	0.55**	0.39**	-0.25*	-0.25	
Stem girth at maturity	1	-0.25*	0.10	0.02	0.15	0.20	0.19	0.24	0.20	-	0.14	0.02	0.31	
	2	-0.35**	0.09	0.11	0.17	0.03	0.37**	0.04	0.55**	-	0.51**	0.08	0.20	
Number of pods/plant	1	0.66**	-0.23	-0.08	-0.11	-0.39**	0.12	0.09	0.15	0.14	-	-0.28*	0.65**	
	2	0.70**	-0.24	-0.11	-0.19	-0.44**	0.24	0.10	0.39**	0.51**	-	-0.23	0.64**	
Weight of 100 Seeds	1	0.12	0.42**	0.09	0.09	0.37**	-0.37**	-0.16	-0.36**	0.02	-0.28*	-	0.11	
	2	0.07	0.48**	0.37**	0.31*	0.32*	-0.20	-0.11	-0.25*	0.08	-0.23	-	0.12	

*, ** = Significant at P≤ 0.05, P≤ 0.01 respectively. 1= first environment and 2= second environment

Discussion

Correlation is a biometrical approach which usually brings out the intensity of the association between two pairs of characters and provides further information on those components that could serve as selection criteria of the candidates in a breeding program. Traits that are positively correlated with yield are considered effective because selection for such traits would result in the simultaneous improvement in yield (Mahalakshmi *et al.*, 2005). Correlation by contrast indicates whether two variables are interdependent or vary together, hence, it is a measure of closeness of association. Similar findings have been reported in groundnut (Yusuf *et al.* 2017; Abdurrasheed *et al.* 2024). It is an established fact that phenotypic character expression incorporates both genotypic and environmental effects. Therefore, the non-significant phenotypic correlation between any two characters, relative to its significant genotypic counterpart, is indicative of appreciable environmental effect. Generally, genotypic relationships are of premium importance in plant breeding. The significant genotypic correlation between yield and “number of pods” per plant in both environments indicates its importance in any groundnut improvement or breeding programme. The significant genotypic correlation between “number of nodes” on the main stem at maturity and final plant height implied that “number of nodes” on the main stem could be increased by selecting for taller genotypes. However, negative correlation of yield with “days to 50 % flowering”, “days to maturity”, “final plant height” and “number of nodes” on the main stem indicates that breeding programme aimed at improving yield must use groundnut genotypes that are early maturing and dwarf. The latter corroborates that of Kaul *et al.* (1998) that “days to first harvest” correlated with “pod yield” negatively in okra. Positive genotypic correlation between “yield per plant” and “number of leaves per plant”, “number of branches” per plant at flowering, “stem girth at maturity” and “weight of 100 seeds” implied that they constituted the components of yield in this population of groundnut. This corroborates studies by Bhavya *et al.* (2017). Consequently, direct selection for these characters in the early segregating generations will be effective and can therefore be exploited for genetic improvement of yield among wide collection of groundnut germplasm (Ojo, 2003).

The high environmental correlation of “yield per plant” with “number of leaves at flowering”, “number of nodes” on the main stem at maturity, “stem girth” and “number of pods” per plant would imply that selection for higher yield based on the genotypic correlation with these characters alone may not always be successful. The negative environmental correlation of yield with final plant height, “number of branches” per plant at flowering and “number of nodes” on the main stem at maturity indicates significant effect of environmental indices on these traits, suggesting that good plant performance is obtained when plant growth requirements are available and adequate. Furthermore, observed differences in environmental correlations with characters in the first and second environments alluded to the existence of different environmental influence on characters in different growing environments.

The path analysis of yield showed that “number of pods” per plant had the highest positive direct correlation and, this coupled with high positive genotypic correlation; imply that it is very important to yield in groundnut. “Number of branches” had a positive indirect effect on yield through increase in “number of nodes” on the main stem, “final plant height” and number of leaves per plant. This observation is similar to that of Santander *et al.* (2013). “Days to maturity” recorded the highest significant negative direct effect on yield in both environments, coupled with high indirect effect on yield through “days to 50% flowering”. This showed that genotypes with higher number of days to flowering may not always be desirable as a result of reduced height at flowering, final plant height, number of nodes on the main stem, number of pods per plant and yield per plant. A similar result was obtained by Wolde *et al.* (2016) in *Triticum aestivum*. In all, number of pods per plant and number of branches per plant were consistently the most important character in both environments. The inconsistency observed on the direct and indirect effects of some characters on yield is an indication of environmental influence on character behaviour.

Conclusion

The yield of *Arachis hypogea* is basically affected by genotypes, phenotypes, environment, and the interaction between these three factors. The direct and indirect characters showed their importance and relationship in respect to yield in the twenty-two genotypes of *Arachis hypogea*. For the breeding programme that would enhance maximum yield of *Arachis hypogea*, direct and indirect characters with higher levels of importance should be assessed. Out of all the studied characters, “number of pods/plant” consistently had the highest direct significant impact on yield across the two environments, followed by “number of branches at flowering”. Furthermore, “days to 50 % flowering” and “days to maturity” had increased significant indirect effect on yield in the two environments. Thus, the selection of *Arachis hypogea* genotypes with high number of pods/plant, “days to 50% flowering” and “days to maturity may improve *Arachis hypogea* yield in tropical environment.

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