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Character Association Studies in Groundnut (*Arachis hypogaea* L.)

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Abstract

The aim of this study was to evaluate the degree of relationship and association amongst morphological characters of groundnut as an important food crop in Nigeria. 118 cultivars were planted in a completely randomized design structure. Characterization was based on qualitative and quantitative evaluations of 62 characters. Data were analysed on the SPSS software (20.0 versions). Correlation tools were applied using Spearman, Kendall and Pearson methods. Level of relationship was determined based on the strength of coefficients R. Dependence among traits was tested using the Chi square. Multiple regression analysis was carried out in a predictive model. As a result, many of the traits are very weakly correlated. Day to emergence has no effect on Day to 50% flowering (R = 0.237, $p < 0.05$) and number of flower (R = 0.221, $p < 0.05$). Day to first flowering weakly correlates with maturity time of the plant (R = 0.39, $p < 0.01$) but no effect on the yield. Also, number of flower correlates moderately with number of pods (R = 0.535, $p < 0.01$) and seeds (R = 0.409, $p < 0.01$). Plant height also moderately affects leaflet sizes (R = 0.354, $p < 0.01$) with a low R^2 of 13%. Plant biomass moderately affects number of pod (R = 0.494, $p < 0.01$), pod length (R = 0.395, $p < 0.01$), pod width (R = 0.473, $p < 0.05$), number of seed (R = 0.468, $p < 0.01$) and seed weight (R = 0.548, $p < 0.01$). Most of the high positive correlations recorded (R > 0.6, $p < 0.9$) were observed amongst pod and seed parameters. Pod sizes significantly affect the number of seeds present (R = 0.551, $p < 0.01$) with R^2 of 30%. Qualitative traits have no effect on each other as all coefficients are very low. Pod constriction and sizes have no relationship (R = −0.029). Tolerance to diseases is not affected by any qualitative trait. Also, no trait determines seed colour. Pubescence of young and mature leaflets recorded the only high positive correlation among all qualitative traits (R = 0.837, $p = 0.01$). However, leaf and stem pubescence have no relationship. The following traits significantly depend on cultivar type: disease tolerance (χ^2 = 17.93, p = 0.000), plant survivorship (χ^2 = 39.97, p = 0.000) and pod yield (χ^2 = 69.695, p = 0.008). Seed yield has been predicted in a fit model with R^2 of 51% and significant p values ($p < 0.05$) among some predictors. When appropriately applied, the information provided in this report may be useful to groundnut growers and breeders as well those interested in systematic studies of the crop.

Keywords

Groundnut, Qualitative Characters, Quantitative Relationship, Breeding, Systematics

1. Introduction

Groundnut (*Arachis hypogaea* L.) is an important food crop popularly cultivated for its seed consumption. Nigeria is globally ranked as the third largest groundnut producing country and the largest producer in Africa [1]. The crop has helped fight malnutrition in Africa as the seed is nutritionally rich [2]. Breeding effort is ongoing to meet different purposes [3] [4] [5]. The crop has been largely characterized morphologically for improvement purposes, but previous studies only captured few landraces or cultivars using limited traits [6] [7]. Morphological traits which are the phenotypic expression of genetic information [8] [9] [10] [11] are grouped into two: quantitative and qualitative traits. The latter is controlled by one or few genes while the former is controlled by interactions of many genes called polygenes [12] [13]. Characters interrelate to contribute to the overall function of plant and they may relate positively or negatively [12] [14] [15]. The degree of relationship may be explored as morphological markers to monitor inheritance or likely appearance of other characters. When two characters are closely related, improving one of the characters may affect the other character [16]. Character association is a basic tool in plant breeding and systematics [3] [8] [10] [12] [14].

Nigeria is committed to high productivity of groundnut as the highest producer in Africa. Despite this, comprehensive information on the interrelationship amongst traits of the crop is scarce and often misapplied. The aim of the present study was to evaluate the degree of relationship and association among selected characters of groundnut cultivars. The outcome may help users of the information make decisions in cultivar selection. This is a technical approach that may save time and resources in the evaluations of traits that are not instantly measurable. It may also provide useful information that will unravel the complex nature of factors affecting the overall survival and yield of the crop.

2. Materials and Methods

118 cultivars of groundnut (*Arachis hypogaea* L.) were planted at the University of Agriculture Makurdi Research Farm (Latitude 07˚45.53'N; Longitude 008˚37.41'E

99 metres above sea level). Farm sized used was 891.75 m^2. Seeds were sowed on 41 long ridges with an inter ridge distance of 0.75 m. The entire field was partitioned into two: Plot 1 and 2. Planting was done in a perpendicular orientation to the ridges. One (1) seed of each cultivar was sowed and replicated 5 times within 1m space on the ridges. This was done for all 118 cultivars in each plot. The design structure was a completely randomized design in a 118 × 5 × 2 arrangement. Therefore, a total of 1180 plant stands were assessed. Characterization was based on qualitative and quantitative evaluations of accessions [17]. A total of 62 characters were evaluated as listed in Table 1.

Computation was done in Excel work book. Data was analysed on the SPSS software (20.0 versions). Correlation analysis was applied on Qualitative traits

Table 1. List of characters evaluated in *Arachis hypogaea.*

	Qualitative Characters		Quantitative Characters
1.	Growth habit	1.	Days to emergence
2.	Stem branching pattern	2.	Stand count (plot 1)
3.	Stem pigmentation	3.	Stand count (plot 2)
4.	Stem hairiness	4.	Days to first flowering
5.	Lateral branch habit	5.	Days to 50% flowering
6.	Leaf colour	6.	Percent survival (%)
7.	Hairiness of young leaflets	7.	Days to maturity
8.	Hairiness of mature leaflets	8.	Number of flowers per inflorescence
9.	Standard petal colour	9.	Pedicel length (cm)
10.	Standard petal markings	10.	Length of floral whorl (cm)
11.	Leaflet texture	11.	Flower length (cm)
12.	Leaflet base	12.	Number of sepal
13.	Leaflet shape	13.	Number of petal
14.	Leaflet apex	14.	Number of branches @day60
15.	Leaf type and description	15.	Plant heigth@day60 (cm)
16.	Traces of diseases	16.	Leaflet length (cm)
17.	Floral symmetry	17.	Leaflet width (cm)
18.	Whorl adhesion	18.	Leaf petiole length (cm)
19.	Whorl cohesion	19.	Stem circumference (cm)
20.	Petal shape	20.	Wet Plant biomass (g)
21.	Pod beak	21.	Dry Plant biomass (g)
22.	Pod constriction	22.	Moisture content (%)
23.	Seed colour	23.	Number of pod/plant
24.	Germination type	24.	Pod length (cm)
25.	Fruit type	25.	Pod width (cm)
26.	Root system	26.	Pod weight (g)
27.	Leaflet venation	27.	Number of seeds/plant
28.	Shell texture	28.	Seed weight (g)
29.	Shell colour	29.	Seed length (cm)
30.	Pollination type	30.	Seed width (cm)
31.	Distribution of flower	31.	Shell weight

using the Spearman's Rank and the Kendall Tau's methods of correlation. Pearson's Product Moment Correlation method was applied on quantitative characters. Significant correlations were flagged at 0.05 and 0.01 levels. Strength of relationship was classified as follows: Weak (0.00 - 0.39), Moderate (0.40 - 0.69), High (0.70 - 0.89) and Very high (0.90 - 1.00) correlations [9] [12]. Dependence among traits was tested using Chi square at 0.05 level of significance. Multiple regression analysis was carried out using a predictive model for seed yield. The equation connecting seed yield and the determinants followed a multiple regression patterns of $Y = a + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4 + B_5X_5 + B_6X_6$. [18] [19].

3. Results and Discussion

Table 2 gives the Pearson's correlation matrix of 26 quantitative traits. Most of the traits are very weakly correlated either positively or negatively. Day to emergence weakly correlates with Day to 50% flowering (R = 0.237, $p < 0.05$) and Number of flower (R = 0.221, $p < 0.05$). Emergence of first shoot does not affect the number of flower produced. Day to first flowering correlates with Day to maturity (R = 0.39, $p < 0.01$), Pod length (R = 0.237, $p < 0.05$), pod weight (R = 0.292, $p < 0.01$), number of seed (R = 0.324, $p < 0.01$) and seed weight (R = 0.345, $p < 0.01$). These are all weak relationships. It appears that timing of flowering significantly affects the maturity time of groundnut but no effect on the yield. Number of flower correlates with number of pods (R = 0.535, $p < 0.01$), pod length (R = 0.285, $p < 0.05$), pod weight (R = 0.312, $p < 0.01$), number of seeds (R = 0.409, $p < 0.01$) and seed weight (R = 0.295, $p < 0.05$). Thus flower production capacity tends to moderately affect both the pod and seed production potential of the plant (yield) but no effect on the sizes of pod and seed.

Length of floral whorl largely affects the petiole length of the flower with a significant correlation coefficient of 0.865 ($p < 0.01$). These characters have no effect on any vegetative and reproductive trait. Plant height moderately correlates with leaflet length only (R = 0.354, $p < 0.01$) indicating that tall cultivars are likely to develop long leaflets. The extent to which these traits affect each other (R^2) is 13%. Other factors that may determine the sizes of leaflets account for 87%. Thus, height of the crop is not a good indicator of leaf sizes. When groundnut is used as a folder crop in animal feeds, cultivars with excellent combination of the two characters may be selected. Plant biomass moderately correlates with number of pod (R = 0.494, $p < 0.01$), pod length (R = 0.395, $p < 0.01$), pod width (R = 0.473, $p < 0.05$), number of seed (R = 0.468, $p < 0.01$) and seed weight (R = 0.548, $p < 0.01$). It appears that overall weight of the plant in the field has significant effect on yield as well as sizes of pods and seeds. From theory, plant biomass is a function of gravity, proplasmic content and water relationship. This suggests that the crop needs maximum care to maintain good biomass. From the matrix, plant biomass has no relationship with other vegetative traits such as plant height and leaf sizes.

Most of the high positive correlations recorded were observed amongst pod and seed parameters. Number of pod correlates with pod weight (R = 0.674,

Table 2. Pearson's correlation matrix among quantitative traits.

	DTE	DFF	D50F	SCP1	SCP2	PSV	DTM	NF1	PL	LFW	FL	NB60	PH60	NN	LLL	LP	SCM	PBM	ANP	PDL	PDw	APDW	ANS	ASW	SL	Sw
DTE	1	−0.20*	0.237*	0.027	−0.047	−0.015	−0.31**	0.221*	0.037	0.004	0.061	0.067	−0.103	0.176	−0.043	−0.30**	0.088	−0.050	0.073	0.041	−0.124	−0.106	−0.188	−0.19*	0.100	−0.086
DFF	−0.205	1	−0.28**	0.102	−0.126	−0.007	0.398**	0.098	−0.084	−0.019	−0.156	−0.069	−0.015	−0.062	−0.061	−0.035	−0.09	0.142	0.047	0.237*	0.199*	0.292**	0.324**	0.345**	−0.065	−0.112
D50F	0.237*	−0.28**	1	−0.090	−0.022	−0.070	−0.044	−0.012	−0.095	0.018	−0.084	0.111	−0.095	−0.037	0.041	−0.29**	0.023	−0.015	0.063	−0.026	−0.157	−0.039	−0.087	−0.084	−0.053	−0.200*
SCP1	0.027	0.102	−0.090	1	0.341**	0.825**	−0.171	0.083	0.058	−0.064	0.042	−0.088	0.239*	0.252**	0.016	−0.145	0.020	0.155	0.095	0.064	−0.045	0.103	0.054	0.164	−0.094	−0.146
SCP2	−0.047	−0.126	−0.022	0.341**	1	0.811**	−0.239	−0.188	−0.028	0.067	−0.021	−0.160	0.058	0.008	0.077	0.078	−0.04	0.016	−0.123	−0.079	−0.081	−0.107	−0.156	−0.062	−0.172	−0.192*
PSV	−0.015	−0.007	−0.070	**0.825****	**0.811****	1	−0.24*	−0.059	0.011	0.002	0.004	−0.150	0.180	0.157	0.059	−0.041	−0.01	0.109	−0.013	−0.005	−0.072	0.002	−0.058	0.067	−0.160	−0.209*
DTM	−0.31*	0.39**	−0.044	−0.171	−0.23*	−0.24*	1	−0.025	−0.056	0.123	0.001	0.231*	−0.26**	−0.196	−0.27**	0.018	−0.04	0.253**	0.081	0.119	0.315**	0.150	0.307**	0.265**	0.191*	0.130
NFI	0.221*	0.098	−0.012	0.083	−0.188	−0.059	−0.025	1	−0.112	0.097	−0.066	0.013	0.038	0.051	−0.085	−0.022	−0.10	0.264**	0.535**	0.285**	0.229*	0.312**	0.409**	0.295**	0.177	0.115
PL	0.037	−0.084	−0.095	0.058	−0.028	0.011	−0.056	−0.112	1	−0.61**	0.865**	−0.128	0.103	0.137	0.090	0.084	0.099	0.123	0.099	0.073	−0.073	0.066	0.014	0.002	0.158	0.261**
LFW	0.004	−0.019	0.018	−0.064	0.067	0.002	0.123	0.097	**−0.61****	1	−0.172	0.250**	−0.20*	−0.170	−0.179	−0.068	−0.10	0.000	0.021	−0.040	0.190	0.007	0.091	0.085	−0.038	−0.045
FL	0.061	−0.156	−0.084	0.042	−0.021	0.004	0.001	−0.066	**0.865****	−0.172	1	−0.014	0.010	0.068	0.013	0.064	0.104	0.157	0.135	0.056	0.039	0.080	0.065	0.047	0.185	0.292**
NB60	0.067	−0.069	0.111	−0.088	−0.160	−0.150	0.231*	0.013	−0.128	0.250**	−0.014	1	−0.032	0.091	−0.104	−0.134	0.012	0.012	0.117	0.052	0.054	0.128	0.186	0.171	0.172	0.152
PH60	−0.103	−0.015	−0.095	0.239*	0.058	0.180	−0.26**	0.038	0.103	−0.200	0.010	−0.032	1	0.617**	0.354**	0.053	0.035	0.001	0.060	0.086	−0.120	0.031	0.026	0.080	−0.059	0.033
NN	0.176	−0.062	−0.037	0.252**	0.008	0.157	−0.19*	0.051	0.137	−0.170	0.068	0.091	0.617**	1	0.315**	−0.058	0.119	0.024	0.067	0.067	−0.23*	0.072	−0.070	0.033	0.079	0.116
LLL	−0.043	−0.061	0.041	0.016	0.077	0.059	−0.27**	−0.085	0.090	−0.179	0.013	−0.104	0.354**	0.315**	1	−0.062	−0.15	0.077	−0.065	−0.062	−0.111	−0.040	−0.078	−0.077	−0.060	−0.118
LP	−0.30**	−0.035	−0.29**	−0.145	0.078	−0.041	0.018	−0.022	0.084	−0.068	0.064	−0.134	0.053	−0.058	−0.062	1	0.124	−0.015	0.119	−0.027	0.185	0.101	0.137	0.091	0.126	0.198*
SCM	0.088	−0.096	0.023	0.020	−0.043	−0.012	−0.045	−0.100	0.099	−0.106	0.104	0.012	0.035	0.119	−0.155	0.124	1	−0.024	−0.104	0.048	0.135	−0.009	0.001	0.017	0.016	−0.014
PBM	−0.050	0.142	−0.015	0.155	0.016	0.109	0.253**	0.264**	0.123	0.000	0.157	0.012	0.001	0.024	0.077	−0.015	−0.02	1	0.494**	0.395**	0.473**	0.382**	0.468**	0.548**	0.293**	0.156
ANP	0.073	0.047	0.063	0.095	−0.123	−0.013	0.081	0.535**	0.099	0.021	0.135	0.117	0.060	0.067	−0.065	0.119	−0.10	0.494**	1	0.442**	0.355**	0.674**	0.698**	0.571**	0.276**	0.226*
PDL	0.041	0.237*	−0.026	0.064	−0.079	−0.005	0.119	0.285**	0.073	−0.040	0.056	0.052	0.086	0.067	−0.062	−0.027	0.048	0.395**	0.442**	1	0.522**	0.738**	0.551**	0.531**	0.477**	0.314**
PDw	−0.124	0.199*	−0.157	−0.045	−0.081	−0.072	0.315**	0.229*	−0.073	0.190	0.039	0.054	−0.120	−0.23*	−0.111	0.185	0.135	0.473**	0.355**	**0.522****	1	0.468**	0.476**	0.491**	0.328**	0.252**
APDW	−0.106	0.292**	−0.039	0.103	−0.107	0.002	0.150	0.312**	0.066	0.007	0.080	0.128	0.031	0.072	−0.040	0.101	−0.00	0.382**	**0.674****	**0.738****	**0.468****	1	0.679**	0.609**	0.349**	0.282**
ANS	−0.188	0.324**	−0.087	0.054	−0.156	−0.058	0.307**	**0.409****	0.014	0.091	0.065	0.186	0.026	−0.070	−0.078	0.137	0.001	0.468**	**0.698****	**0.551****	**0.476****	**0.679****	1	0.826**	0.279**	0.208*
ASW	−0.19*	0.345**	−0.084	0.164	−0.062	0.067	0.265**	0.295**	0.002	0.085	0.047	0.171	0.080	0.033	−0.077	0.091	0.017	**0.548****	**0.571****	**0.531****	**0.491****	**0.609****	**0.826****	1	0.195*	0.160
SL	0.100	−0.065	−0.053	−0.094	−0.172	−0.160	0.191*	0.177	0.158	−0.038	0.185	0.172	−0.059	0.079	−0.060	0.126	0.016	0.293**	0.276**	**0.477****	0.328**	0.349**	0.279**	0.195*	1	0.696**
Sw	−0.086	−0.112	−0.20*	−0.146	−0.192	−0.20*	0.130	0.115	0.261**	−0.045	0.292**	0.152	0.033	0.116	−0.118	0.198*	−0.01	0.156	0.226*	0.314**	0.252**	0.282**	0.208*	0.160	**0.696****	1

Legend: DTE = Day to emergence, DFF = Day to first flowering, D50F = Day to 50% flowering, SCP1 = Stand count at plot 1, SCP2 = Stand count at plot 2, PSV = Percentage survival, DTM = Day to maturity, NFI = Number of flower, PL = Pedicel length, LFW = Length of floral whorl, FL = Flower length, NB60 = Number of branches at day 60, PH60 = Plant height at day 60, NN = Number of nodes, LLL = Leaflet length, PBM = Plant biomass, ANP = Average number of pod, PDL = Pod length, PDw = Pod width, APDW = Average pod weight, ANS = Average number of seed, ASW = Average seed weight, SL = Seed length, Sw = Seed width 0.00 - 0.39 = very weak and low correlation; 0.40 - 0.69 = moderate correlation; 0.70 - 0.89 = high correlation; 0.9 - 1.00 = very high correlation. *Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed).

$p < 0.01$) and number of seeds (R = 0.698, $p < 0.01$). To achieve maximum seed yield, high pod yield is necessary. Pod length and width significantly affects pod weight (R = 0.738, $p < 0.01$) and the number of seeds present (R = 0.551, $p < 0.01$). The coefficient of determination between pod sizes and number of seed (R^2) is 30%. Large pod may therefore determine the number of seeds it contains to an extent. 70% of this relationship is accounted for by other unknown factors. As observed in the field, some large pods may contain fewer numbers of seeds than small pods most especially when the seeds are of big sizes. Seed weight and number of seeds produced per plant are highly correlated (R = 0.826, $p < 0.01$).

Table 3 presents the Kendall's correlation matrix among qualitative traits with varying features. Qualitative traits have no effect on each other as all coefficients are very low. Those with significant values are very weakly related. Growth habit correlates with stem branching pattern (R = 0.214, $p = 0.01$) and standard petal colour (R = 0.221, $p = 0.01$). These are very weak relationships. Growth could assume any habit (procumbent, decumbent or erect) irrespective of all stem morphological features such as branching pattern, pigmentation and lateral branching habit. Growth habit has no relationship with all other qualitative characters as all coefficients of relationship are very weak and insignificant.

Table 3. Kendall's correlation matrix of qualitative characters with varying features.

	GH	SBP	SP	SH	LBH	LC	HYL	HML	SPC	LTX	TD	PB	PC	SC
GH	1	0.213**	−0.053	0.057	0.106	0.027	0.014	0.059	0.188*	−0.134	0.081	0.028	0.007	0.017
SBP	0.213**	1	0.002	−0.126	0.04	0.091	−0.045	0.019	0.056	−0.079	−0.009	0.012	0.097	0.05
SP	−0.053	0.002	1	0.062	0.127	−0.193*	0.149	0.109	−0.084	−0.064	0.067	−0.086	0.043	0.028
SH	0.057	−0.126	−0.062	1	−0.069	−0.033	−0.019	−0.063	0.221*	0.145	0.068	0.007	0.037	0.171
LBH	0.106	0.04	0.127	−0.069	1	−0.039	0.026	0.079	0.182*	−0.026	−0.031	0.019	0.068	−0.01
LC	0.027	0.091	−0.193*	−0.033	−0.039	1	−0.048	−0.015	−0.015	0.16	0.128	0.094	−0.049	−0.141
HYL	0.014	−0.045	0.149	−0.019	0.026	−0.048	1	0.837**	0.146	0.125	−0.081	0.067	0.063	−0.046
HML	0.059	0.019	0.109	−0.063	0.079	−0.015	0.837**	1	0.113	0.12	−0.06	0.075	0.053	−0.046
SPC	0.188*	0.056	−0.084	0.221*	0.182*	−0.015	0.146	0.113	1	0.002	−0.126	0.063	0.018	−0.121
LTX	−0.134	−0.079	−0.064	0.145	−0.026	0.16	0.125	0.12	0.002	1	−0.061	0.054	−0.063	0.035
TD	0.081	−0.009	0.067	−0.068	−0.031	0.128	−0.081	−0.06	−0.126	−0.061	1	−0.099	−0.087	−0.028
PB	0.028	0.012	−0.086	0.07	0.019	0.094	0.067	0.075	0.063	0.054	−0.099	1	.284**	0.329**
PC	0.007	0.097	0.043	0.037	0.068	−0.049	0.063	0.053	0.018	−0.063	−0.087	0.284**	1	0.285**
SC	0.017	0.05	0.028	0.171	−0.01	−0.141	−0.046	−0.046	−0.121	0.035	−0.028	0.329**	.285**	1

Legend: Code: GH, **Character:** growth habit, **Variables:** Procumbent, Decumbent, Erect; **Code:** SBP, **Character:** stem branching pattern, **Variables:** Alternate, Sequential, Irregular with flowers on main stem, Irregular without flowers on main stem; **Code:** SP, **Character:** stem pigmentation, **Variables:** Green, Brown; **Code:** SH, **Character:** stem hairiness, **Variables:** Scarce, Abundant, Very abundant; **Code:** LBH, **Character:** lateral branch habit, **Variables:** Distichous, Non-distichous; **Code:** LC, **Character:** leaf colour, **Variables:** Dark green, Light green; **Code:** HYL, **Character:** hairiness of young leaflet, **Variables:** Almost glabrous, Sparse and short, Sparse and long, Profuse and short, Profuse and long; **Code:** HML, **Character:** hairiness of mature leaflet, **Variables:** Almost glabrous, Sparse and short, Sparse and long, Profuse and short, Profuse and long; **Code:** SPC, **Character:** standard petal colour, **Variables:** Yellow only, Yellow with white patches; **Code:** LTX, **Character:** leaf texture, **Variables:** Hard, Soft; **Code:** TD, **Character:** traces of disease, **Variables:** Susceptible, Resistant; **Code:** PB, **Character:** pod beak, **Variables:** Absent, Slight, Moderate, Prominent, Very prominent; **Code:** PC, **Character:** pod constriction, **Variables:** None, Slight, Moderate, Deep, Very deep; **Code:** SC, **Character:** seed colour, **Variables:** Rosy pink, Rosy brown, Chimeric. *Correlation is significant at the 0.05 level (2-tailed); **Correlation is significant at the 0.01 level (2-tailed).

Stem hairiness also recorded very weak relationships with all qualitative characters. The only significant correlation between this trait and standard petal colour (R = 0.221, p = 0.01) was a very weak value. Pod beak and constriction pattern are significantly correlated (R = 0.284, p = 0.01) but very weak. The absence or prominence of beak does not affect the constriction pattern. Pod could have slight or moderate or deep or very deep constriction regardless of other qualitative characters. Tolerance to diseases is not affected by any of the qualitative traits. Also, no trait determines seed colour. The only high positive correlation observed among all qualitative traits is between hairiness of young and mature leaflets (R = 0.837, p = 0.01). Hairiness is classified as: Almost glabrous, Sparse/Short, Sparse/Long, Profuse/Short and Profuse and long. Pubescence level in young leaflets determines level and nature of pubescence in the mature leaflets of a particular plant. However, leaf and stem pubescence have no relationship.

Table 4 shows the relationship between Pod constriction and Pod size as revealed by Spearman and Kendall's method. Pod constrictions had very low negative correlation with Pod sizes in the two non-parametric correlations (Kendall R = 0.029; Spearman R = 0.038). Pods could be slightly or moderately or deeply constricted irrespective of their sizes.

Chi square tests (Table 5) revealed significant associations among the variables tested ($p < 0.05$): Cultivar type and Disease susceptibility (χ^2 = 17.93, p = 0.000); Cultivar type and Plant survivorship (χ^2 = 39.97, p = 0.000); Cultivar type and Pod production (χ^2 = 69.695, p = 0.008).

The equation connecting seed production capacity and six other regressors is given in Table 6. Among the regressors, Plant biomass PB (p = 0.035) and Number of pods NP (p = 0.00) were significant on seed production. Seed yield could be predicted by substituting the values of the predictors in the linear equation:

$$
\begin{aligned}
Y = 7.463 + 0.181(\text{NF}) - 0.733(\text{FS}) + 0.011(\text{PH}) \\
- 0.886(\text{LS}) + 0.019(\text{PB}) + 0.889(\text{NP})
\end{aligned}
$$

where: Y = number of seed, NF = number of flower, FS = length of the flower, PH = plant height, LS = leaflet length, PB = plant biomass, NP = number of pod. This level of relationship is confirmed in the scattergram of partial regression plots shown in Figures 1-4. Predicting the number of seed produced is necessary

Table 4. Spearman rank and Kendall's tau correlations between pod constriction and pod size.

Method			Pod constriction	Pod size
Kendall Tau	Pod constriction	r	1.000	−0.029
	Pod size	r	−0.029	1.000
Spearman	Pod constriction	r	1.000	−0.038
	Pod size	r	−0.038	1.000

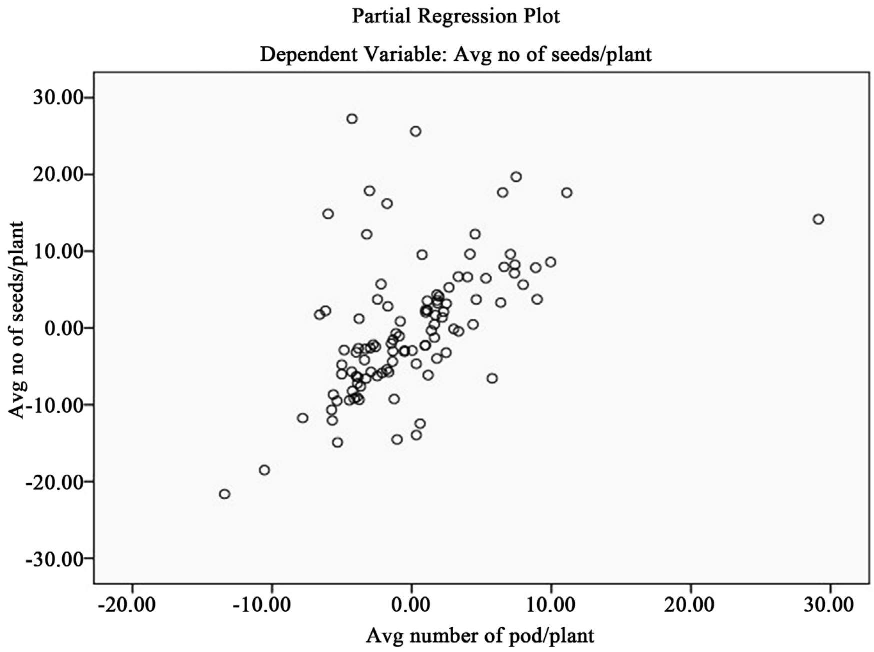

Figure 1. Regression plot of number of seed and number of pod per plant.

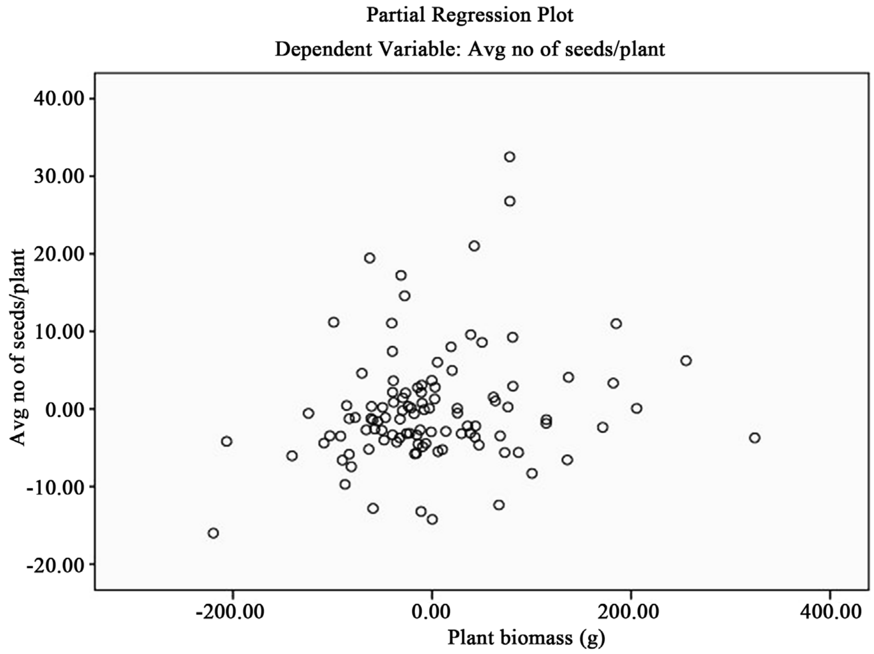

Figure 2. Regression plot of number of seed and plant biomass.

Table 5. Chi square tests between cultivar type and other characters.

Cultivar	Disease susceptibility	Plant survivorship	Pod production
χ^2	17.93	39.97	63.70
D.F	1	9	39
p-value	0.000	0.000	0.008

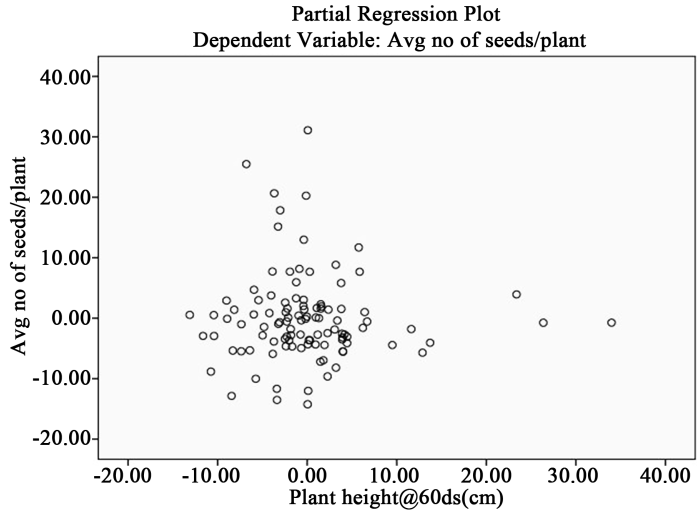

Figure 3. Regression plot of number of seed and plant height.

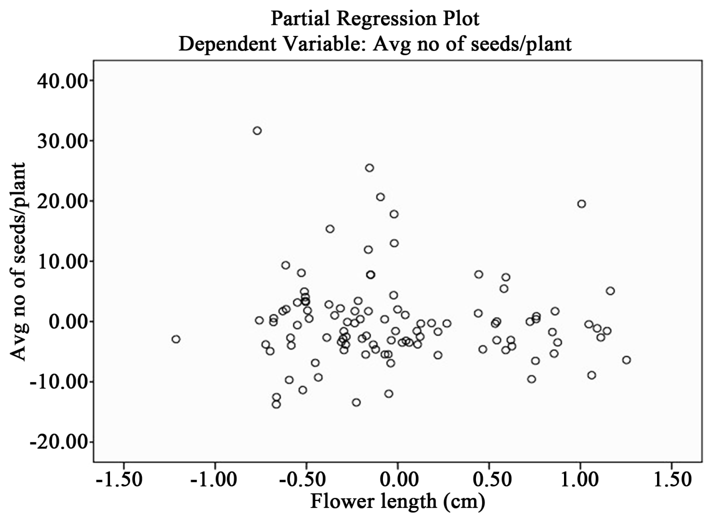

Figure 4. Regression plot of number of seed and flower size.

Table 6. Regression coefficients and equation for groundnut seed production.

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	7.463	8.272		0.902	0.369
	No of flowers /inflorescence (NF)	0.181	0.383	0.040	0.471	0.638
	Flower size (FS)	−0.733	1.350	−0.039	−0.543	0.588
	Plant height (PH)	0.011	0.115	0.007	0.092	0.927
	Leaflet size (LS)	−0.886	1.318	−0.051	−0.672	0.503
	Plant biomass(PB)	0.019	0.009	0.175	2.138	0.035
	Number of pod/plant (NP)	0.889	0.141	0.591	6.315	0.000

Seed Yield (Y) = 7.463 + 0.181(NF) − 0.733(FS) + 0.011(PH) − 0.886(LS) + 0.019(PB) + 0.889(NP). a. Dependent Variable: No of seeds/plant.

after pod harvesting when pods are to be stored for a long time without break. The coefficient of relationship of the overall model is 0.716. This model explains 51% of variation in seed production (R^2 = 51.3%) hence a fit model. 48% of variation in seed production is not accounted for the predictors (Table 7).

In the present report, *Arachis hypogaea* can be described as a crop having moderate level of character association in quantitative traits. This is contrary to the findings in other crops where quantitative characters are very highly related [9] [10] [12]. High level of character divergence in vegetative features has many implications. It implies high level of diversity which may form the basis of varietal separation [11] [20]. The major botanical varieties of *Arachis hypogaea* L. were previously classified based on foliar and stem morphological differences [6] [20]. It also implies that genes coding for the vegetative traits are not linked together in groundnut and that no trait could be used as a morphological marker of other vegetative characters. For instance, Leaflet sizes could be small or large irrespective of the plant height among the cultivars.

Most vegetative and reproductive traits are not related. This may hinder breeding practice of indirect selection on the crop because cultivars cannot be easily selected for pod yield on the basis of plant height or leaf sizes or the growth pattern of standing plants in the field before they are harvested. Over the years, most improvement program on groundnut targeted yield related parameters [3] [5] [11]. Therefore, any trait or attribute that may help predict or improve yield would attract the attention of groundnut breeders. The observed moderate correlation between plant biomass and seed weight could be attributed to normal physiological processes such as water absorption potentials and photosynthetic activities [19] [21]. Larger canopies may manufacture more food to be deposited in the seed as food reserves [21]. Adequate water intake is also needed for seed production in groundnut [22] [23].

The present report totally agrees with other studies where high correlations in reproductive characters have been reported [9]. It is expected that sizes of pods should determine the sizes and number of seeds present. The number of seed should also correlate well with its weight. Breeders aiming at improving seed yield may then focus only on improving the crop for pod yield and pod sizes regardless of the constriction pattern of the pod. Similar findings were previously reported on the crop [6] [7]. It is also expected that the length of pedicel should determine the overall size of the flower, though this is unrelated with pod and seed yield. The present report has buttressed basic genetic theories. Traits such as disease susceptibility, plant survivorship and pod production depend on the type of cultivar. This may be due to the inherent genetic differences among the

Table 7. Model summary for groundnut seed production.

Model	R	R Square	Adjusted R^2	Std. Error of the Estimate
1	0.716[a]	0.513	0.483	7.60002

[a]Predictors: (Constant) : NF, FS, PH, LS, PB, NP.

cultivars [8] [9] [11]. Hence, selection for or against these traits in groundnut should be cultivar dependent only. It appears that the two traits that can help predict seed production in groundnut are pod yield and plant biomass, although a large proportion (48%) of seed production determinant is unaccounted for.

Pod yield is a quantitative trait which may involve the interactions of polygenes. This trait thus requires QTL (Quantitative Trait Loci) analysis for a more detailed explanation. The plant biomass factor is a weight related factor and cannot be separated from the moisture content of the plant. This implies that the crop requires high amount of water for maximum pod and seed production. Groundnut pods, as the name implies, are buried underground and they are attached to the plant root system where water absorption takes place. This information accounts for why the crop is popularly cultivated in the raining season in Nigeria [22].

From the present report, qualitative traits do not affect each other. Hence they cannot be used as morphological markers of other traits. Any qualitative feature cannot be predicted by physical observation of any other trait. They all show a wide separation of relationship but are excellent features that provide systematic resolution. Traits such as growth habit, branching pattern, stem pigmentation, pod characteristics and seed colour can help differentiate cultivars. Among the qualitative traits, only disease resistant cultivars could be of interest to breeders.

4. Conclusion

The present study has successfully determined the level and nature of relationships among all qualitative and quantitative characters of *Arachis hypogaea.* The most significant high levels of relationships were found among quantitative reproductive traits especially in yield related properties. Vegetative characters are weakly related. No relationship was established among all qualitative features with the exception of pubescence of young and mature leaflets. The implications of these results have been extensively discussed. The information provided in this report is very crucial to groundnut growers and breeders as well those interested in systematic studies of the crop.

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