Morphological, agronomic, and isozyme characterization of some accessions of groundnuts (*Arachis hypogaea* L.)

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ABSTRACT

Seventeen accessions of groundnuts (*Arachis hypogaea* L.) were characterized at the University of Ghana, Legon, to identify useful variation for the genetic improvement of the crop. Using morphological and agronomic markers based on six qualitative and 11 quantitative descriptors, wide variations were shown among the accessions. Each of the accessions was distinct except four, which fell into two groups of two each. Starch gel electrophoresis of crude protein extracted from the root-tip tissue of the accessions to study variation in esterase, peroxidase and acid phosphatase, also exposed variations among the accessions. Acid phosphatase showed the most variation while peroxidase showed the least variation. When all of the three isozymes were considered, it was possible to unambiguously distinguish 13 of the 17 accessions. The remaining four fell into two groups of two each. The results of the study indicated that isozymes are useful in the characterization of groundnuts.

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RÉSUMÉ

DANQUAH, E. Y., BLAY, E. T. & FOSU-NYARKO, J.: *Caractérisation morphologique, agronomique et isoenzyme de quelques accessions d' arachides (*Arachis hypogaea *L.).* Dix-sept accessions d'arachides étaient caractérisées à l' Université du Ghana, Legon en vue d' identifier une variation utile pour l'amélioration génétique de la culture. Employant les marqueurs morphologiques et agronomiques basés sur six descripteurs qualitatives et onze quantitatives, des variations étendues étaient révélées parmi les accessions. Chacune des accessions était distincte à l'exception de quatre, qui tombent en deux groupes de deux par chacun. Les gels électrophorèse de fécule de la protéine brute extraits de la tissu de l'extrémité radiculaire des accessions pour étudier la variation en esterase, peroxidase et acide phosphatase aussi exposait les variations parmi les accessions. L'acide phosphatase révélait la plus grande variation alors que peroxidase montrait les plus petites variations. Lorsque tous les trois isoenzymes étaient considérées, elles ont pu distingué sans ambiguïté 13 des 17 accessions. Les quatres qui restent, tombaient en deux groupes de deux par chacun. Les résultats de l'étude indiquaient que les isoenzymes sont utiles à la caractérisation d' arachides.

Introduction

Groundnut (*Arachis hypogaea* L.) is an important grain legume grown predominantly under rain-fed conditions in the semi-arid regions of the world (Rao, 1980). In Ghana, the crop is cultivated mainly in the northern sector and is put to many uses including food and feed for man and animals, respectively, extraction of oil for cooking and for the making of detergents. It is also used in cropping systems as a nitrogen restorer (NARP, 1993). Despite the numerous uses of the crop, production falls well behind demand because yields are very low in the country. Also, the widespread use of a few improved genotypes has led to increased vulnerability to diseases and pests (Simmonds, 1962; NARP, 1993). A way forward to boost production is the development of several high-yielding varieties for specific environments. This can only be achieved if there is variability in the breeding population (Rao, 1980; Norden, 1990; Smith & Smith, 1992). Information on variations among accessions is important not

only for plant breeders, but also for the conservation of genetic resources (Doku, 1970; Bennett-Lartey, 1991). There is a justifiable concern about the extent of genetic diversity used by breeders and farmers (Duvic, 1997; Troyer, Openshaw & Knittle, 1988). Without a continued source of variability, the ability to create new plateaus of agronomic performance that are based on complex genetic combinations could decline. This is because the more diverse the parents of a breeding programme, the greater is the chance of obtaining superior segregants (Simmonds, 1979). Of more immediate concern is that sufficient genetic diversity should be made available to farmers.

To date, all studies on the characterization of germplasm of groundnuts in Ghana have used only morphological and agronomic markers (NARP, 1993; Abban, 1997). The use of such characters, however, does not allow for proper characterization of germplasm, because variation of morpho-agronomic characters is very limited. Additionally, multiple genotypes may give similar phenotypes; so the extent to which similar phenotypes reflect similar genotypes cannot be determined. Furthermore, such characters are influenced by the environment to varying degrees (Patterson & Weathercup, 1984). Molecular markers, e.g. isozymes and RFLPs, have long been recognized as useful markers for the characterization of germplasm (Krapovickas, 1973). The markers overcome the problems associated with the use of morpho-agronomic markers to characterize germplasm. Isozymes, multiple molecular forms of a given enzyme which catalyze the same reaction are, by far, the cheapest, quickest, and most widely used molecular markers (Powell, 1992). They have been used extensively to study variation among collections of groundnuts (Grieshammer & Wynne, 1990; Maass, Torres & Ocampo, 1993; Stalker *et al.*, 1994).

This study aimed at characterizing 17 accessions of groundnuts supplied by the gene bank of the Plant Genetic Resources Centre, Bunso, Ghana, using morphological, agronomic and isozyme markers; and also at exploring the potential of using isozymes as markers for agronomically important traits.

Materials and methods

Field experiment

The study involved 17 accessions supplied by the Plant Genetic Resources Centre, Bunso. The experiment was carried out in the Sinna's garden, at the University of Ghana, Legon, during the minor rainy season of 1997. The soils belong to the Ferric Acrisols. Land was prepared in the 1st week of September, and the soil was treated with Furadan to control nematodes which had infested a previous crop of tomato on the same piece of land. Planting was done in mid-September. The experimental design was a randomized complete block, replicated two times. Plots consisted of single rows, 2.3 m long, spaced 0.6 m apart. Spacing within rows was 0.3 m. There were eight plots per row. Data was collected from the six central plants. The guidelines of IBPGR/ICRISAT (1985) descriptor list were used to collect data on the following characters:

1. Growth habit: procumbent, decumbent, etc.
2. Stem branching pattern.
3. Pigmentation of the mature stem.
4. Beakiness of the pod after harvest.
5. Constriction of pod after harvest.
6. Colour of seed.
7. Number of days from planting to 50 per cent emergence.
8. Number of days from emergence to 50 per cent flowering.
9. Number of days to maturity.
10. Length of fully expanded apical leaflet (mm).
11. Width of fully expanded apical leaflet (mm).
12. Length of reproductive branch at 50 per cent flowering on cotyledonary lateral branch (cm).
13. Length of pod (cm) – mean of 10 mature pods.
14. Width of pot - average of 10 mature pods

(mm).

15. Length of seeds - mean of 10 mature seeds (mm).
16. Width of seeds - mean of 10 mature seeds (mm).
17. 100-seed weight (g).
18. Yield (kg/ha).

Isozyme variation

For the study of isozymes, leaf and root-tip tissues were sampled from one plant per accession. Because of the high content of glycoproteins in the leaves, extraction of proteins was very difficult. Starch gel electrophoresis gave very poor resolution. Hence, studies were limited to root-tip tissue. The methodology for isozyme extraction, running, and staining established by Maass *et al.* (1993) was modified for *A. hypogaea* as follows: about 500 mg of root tissue were macerated in extraction buffer (Table 1). The samples were centrifuged for 20 min at 14 000 rpm in an Eppendorf microcentrifuge. The supernatant (25 ml) was used to conduct electrophoresis in starch gel of 12 per cent concentration. The electrophoresis separation was done at constant voltage (200 volts) at 4 °C for about 5 h. The gels were stained, fixed, and stored according to the method of Ramirez *et al.* (1987). Three isozymes (α- esterase, αβ- acid phosphate, and peroxidase) for which substrates were available, were studied.

TABLE 1

Buffer Systems and Running Conditions for Electrophoresis

Buffer system	Chemical composition
Gel buffer	0.77 g citric acid Monohydrate + 1.66 g Tris per litre Adjusted to *p*H 7.75 with 1 *N* HCl/1 *N* NaOH
Electrode buffer	0.3 *M* boric acid (18.55 g/l) Adjusted to *p*H 8.0 with 1 *N* NaOH
Extractant	A mixture of equal amounts of: (a) 0.2 *M* Tris (2.42 g/100 ml) Adjusted to *p*H 8.0 with 1 *N* HCl (b) 1 % potassium metabisulphite (1 g/100 ml) (c) 0.5 *M* Sucrose (17.12 g/100 ml), *p*H 7.6
The running conditions were: a constant voltage of 200 V, 20 mA, at 4 °C for about 5 h	
Staining requirements for the isozyme studies	
Isozyme	Composition of the staining solution and conditions
Esterase	0.08 *M* Tris, *p*H 7.0, 1 % a-naphtyl acetate (8 ml) Fast blue RR salt (2 g). Stain until blue black pattern appears in the gel.
Peroxidase	50 % m*M* Na-acetate buffer, *p*H 5.0 (50 ml), $CaCl_2$ (50 mg, 1 ml). Hydrogen peroxide 3 %, 0.25 ml, 3-amino-90 ethyl carbozole (25 mg), N, N-Dimethyl Formamide (2 ml). Stain until red bands appear.
Acid phosphatase	50 m*M* Na-acetate buffer, *p*H 5.0 (50 ml), sodium a-napthyl acid phosphatase (50 mg), $MgCl_2$ (50 mg, 1 ml), Fast Garnet GBC salt (50 mg, 1 ml) Stain until red bands appear.

To test for repeatability, electrophoreses were carried out several times with the same plant extract. However, intra-accession variation was not studied.

Analyses of data

For quantitative characters, the mean and range were computed for each accession. The coefficient of variation was also calculated for each character and correlations among them studied. Isozyme bands were scored for the presence or absence of the respective bands, and similarities and differences sorted out considering the positions of the bands in the gel. Differences in staining intensity were ignored, and scoring was done by two people independently to ensure objectivity. Where there were ambiguities, a third score by a different person was allowed. Chi-square tests were performed to determine associations between allozymes and agronomically important traits.

Results

Number of days to emergence, flowering, and maturity

Table 2 shows the mean and range for number of days to 50 per cent emergence, 50 per cent flowering, and 50 per cent maturity for the accessions. The number of days to 50 per cent emergence of the accessions ranged between 5 and 14. Accession 87/168 was the first to attain 50 per cent emergence whereas accession 87/22 was the last in 14 days. There were several early and very late emergers, indicating variation for this character (Table 2). The coefficient of variation (CV) was 31.56 per cent. For number of days to 50 per cent flowering, accession 87/36 was the first

TABLE 2

Means, Ranges, and Coefficient of Variation for Days to 50 % Emergence (DFE), 50 % Flowering (DFF) and 50 % Maturity (DTM) for 17 Accessions of Groundnuts Studied

	DFE		*DFF*		*DTM*	
Accession	*Mean*	*Range*	*Mean*	*Range*	*Mean*	*Range*
87/13	7 ± 0.3	5 - 9	25 ± 1.0	25 - 26	101 ± 0.9	100 - 104
87/21	11 ± 0.6	10 - 12	29 ± 0.5	25 - 31	103 ± 0.3	99 - 108
87/22	14 ± 1.4	7 - 18	27 ± 2.7	26 - 30	100 ± 2.4	99 - 101
87/26	7 ± 0.9	4 - 13	29 ± 1.6	25 - 31	107 ± 1.2	106 - 108
87/28	13 ± 0.2	13 - 14	30 ± 0.4	39 - 31	104 ± 0.6	102 - 107
87/31	7 ± 0.3	6 - 11	27 ± 1.5	21 - 31	103 ± 1.1	98 - 108
87/36	6 ± 0.5	4 - 11	24 ± 1.0	24 - 26	106 ± 0.8	103 - 109
87/42	7 ± 0.8	5 - 10	30 ± 0.3	29 - 31	101 ± 0.5	96 - 106
87/54	8 ± 1.3	4 - 11	28 ± 1.0	24 - 30	106 ± 0.9	105 - 107
87/65	7 ± 0.8	6 - 10	29 ± 0.5	28 - 31	106 ± 0.6	105 - 108
87/82	8 ± 1.4	6 - 13	28 ± 1.1	24 - 30	105 ± 1.0	102 - 108
87/84	10 ± 0.5	8 - 12	26 ± 1.5	24 - 30	101 ± 1.6	95 - 105
87/114	7 ± 0.5	6 - 9	28 ± 0.5	26 - 32	105 ± 0.4	102 - 109
87/127	7 ± 0.2	5 - 8	25 ± 0.2	25 - 27	97 ± 0.4	95 - 98
87/128	6 ± 0.5	5 - 9	26 ± 0.9	26 - 27	106 ± 0.7	103 - 109
87/154	6 ± 0.8	5 - 8	29 ± 0.3	28 - 30	103 ± 0.3	102 - 104
87/168	5 ± 0.3	5 - 6	25 + 1.5	24 - 27	106 ± 1.3	104 - 110
CV	31.6 %		7.0 %		2.7 %	

to flower in 21 days after emergence. Accessions 87/28 and 87/42 flowered last in 29 days. The range for days to 50 per cent flowering was 21 to 32. Accession 87/36 registered the shortest time while accessions 87/28 and 87/42 took the longest time (Table 2). The CV for this character was very low (6.95 %). It took between 95 and 110 days after emergence for all of the accessions to mature. Accession 87/127 was the earliest while accessions 87/54, 87/65, 87/128, and 87/168 were the latest. The CV was 2.6 per cent. The number of days to 50 per cent emergence and 50 per cent flowering were negatively correlated with maturity (-0.36 and -0.14, respectively).

Variation in growth habit, branching pattern, and stem pigmentation

Table 3 shows the growth habit, branching pattern, and stem pigmentation of the accessions studied. Four types of growth habits were observed: decumbent-1, decumbent-2, decumbent-3, and erect. None of the accessions was of the procumbent type (Fig. 1a). Four of the accessions were of the decumbent-1 type, whilst six each were of the decumbent-2 and decumbent-3 types. One accession was erect in growth habit. All of the stem branching patterns documented in the IBPGR descriptor list were observed, i.e. alternate, sequential, irregular with flowers on the main stem, and irregular without flowers on the main stem (Fig. 1b). There were five accessions with the sequential branching pattern, and four each of the other patterns (Table 3). For the stem pigmentation, 11 of the accessions were not pigmented, whilst six were pigmented.

TABLE 3

Variations in Growth Habit, Branching Pattern, and Stem Pigmentation in 17 Accessions of Groundnuts Studied

Accession	*Growth habit*	*Branching*	*Stem pigmentation*
87/13	Decumbent-3	3	Absent
87/21	Decumbent-3	3	Absent
87/22	Decumbent-1	2	Present
87/26	Decumbent-1	2	Absent
87/28	Decumbent-3	3	Present
87/31	Decumbent-1	4	Present
87/36	Decumbent-2	2	Absent
87/42	Decumbent-3	4	Absent
87/54	Erect	1	Absent
87/65	Decumbent-1	3	Absent
87/82	Decumbent-2	4	Absent
87/84	Decumbent-2	1	Absent
87/114	Decumbent-3	1	Absent
87/127	Decumbent-2	2	Present
87/128	Decumbent-3	1	Absent
87/154	Decumbent-2	4	Present
87/168	Decumbent-2	2	Present

Key:
1 = Alternate
2 = Sequential
3 = Irregular with flowers on the main stem
4 = Irregular without flowers on the main stem

Variation in leaf characteristics

Table 4 shows the means and ranges for the length and width of the leaflets of the accessions studied. The values ranged from 3.8 to 7.7 mm and 1.8 to 3.5 mm, respectively. The CVs were low; 12.36 per cent for leaflet length, and 9.36 per cent for leaflet width. There was a positive correlation between length and leaflet and yield ($r = 0.29$).

Variation in pod characteristics

Table 5 shows the beakiness and constriction of pods as well as their lengths and widths. Fig. 2a shows the extent of beakiness; slight, moderate or prominent. Two of the accessions (87/82 and 87/84) had no beaks, 10 showed slight beakiness, five had moderate beaks, and none had prominent beak. For pod constriction, eight were slightly constricted; six moderate, and three had pods with deep constriction. The pod length for the accessions ranged from 14.75 to 50.30 mm with a CV of 15.29 per cent. Accession 87/154 produced the longest mean pods whilst accession 87/128

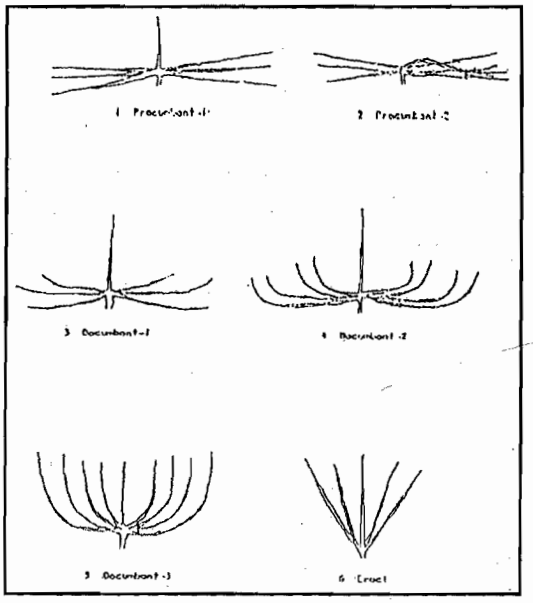

Fig. 1a. Types of growth habit in groundnuts.
Source: IBPGR descriptor list for groundnuts (1993).

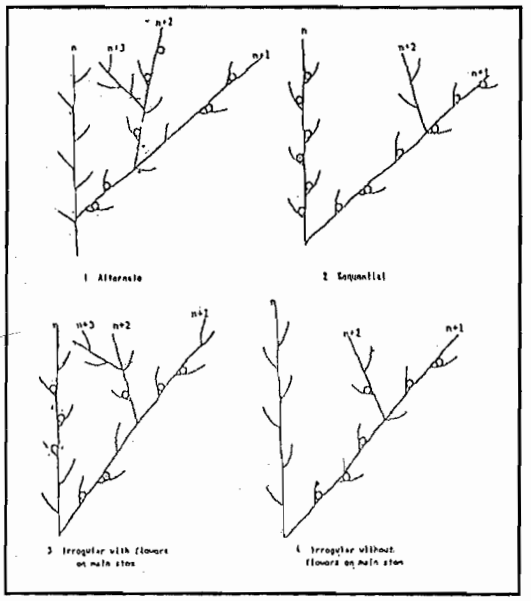

Fig. 1b. Stem branching patterns in groundnuts.

TABLE 4

Means, Ranges of Leaflet Lengths and Widths of 17 Accessions of Groundnuts Studied

	Leaflet length		*Leaflet width*	
Accession	*Mean (cm)*	*Range (cm)*	*Mean (cm)*	*Range (cm)*
87/13	5.66 ± 0.2	5.2 - 6.0	3.18 ± 0.1	2.9 ± 3.5
87/21	4.72 ± 0.3	4.2 - 5.9	2.50 ± 0.1	2.0 - 2.7
87/22	6.04 ± 0.2	5.4 - 6.6	2.96 ± 0.1	2.6 - 3.3
87/26	6.42 ± 0.3	5.0 - 7.4	2.50 ± 0.2	1.9 - 3.3
87/28	4.20 ± 0.4	4.1 - 4.3	2.32 ± 0.1	1.8 - 2.7
87/31	6.25 ± 0.3	5.0 - 7.4	3.02 ± 0.2	2.5 - 3.7
87/36	6.47 ± 0.3	5.2 - 7.3	3.15 ± 0.1	2.7 - 3.6
87/42	4.95 ± 0.3	3.8 - 5.9	2.52 ± 0.1	2.0 - 2.7
87/54	5.94 ± 0.4	4.4 - 7.5	2.97 ± 0.2	2.3 - 3.6
87/65	6.15 ± 0.2	5.0 - 6.9	2.92 ± 0.1	2.4 - 3.3
87/82	6.19 ± 0.4	4.0 - 7.5	3.07 ± 0.1	2.2 - 3.5
87/84	4.90 ± 0.3	4.5 - 5.1	2.90 ± 0.1	2.7 - 3.1
87/114	4.95 ± 0.1	3.8 - 5.9	2.55 ± 0.1	2.1 - 2.8
87/127	6.02 ± 0.3	5.1 - 7.7	3.04 ± 0.1	2.7 - 3.4
87/128	6.05 ± 0.3	5.4 - 7.0	2.89 ± 0.1	2.3 - 3.3
87/154	5.32 ± 0.2	4.6 - 6.5	2.62 ± 0.1	2.4 - 3.0
87/168	6.02 ± 0.2	4.6 - 7.3	2.91 ± 0.1	2.6 - 3.4
CV	12.4 %		9.4 %	

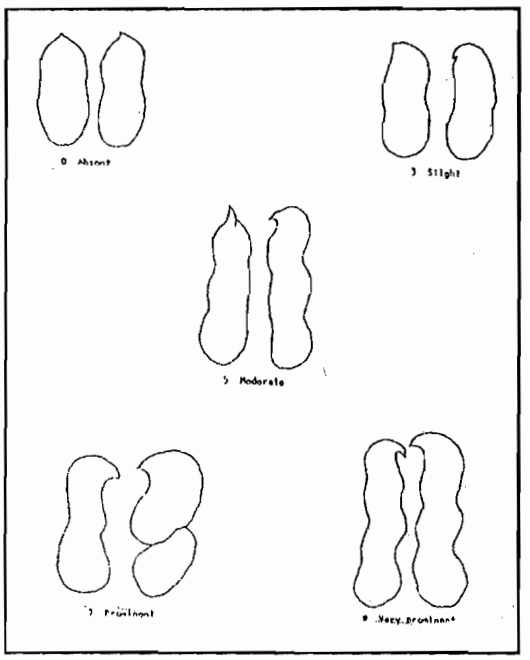

Fig. 2a. Types of pod beak in groundnuts.
Source: IBPGR descriptor list for groundnuts (1993)

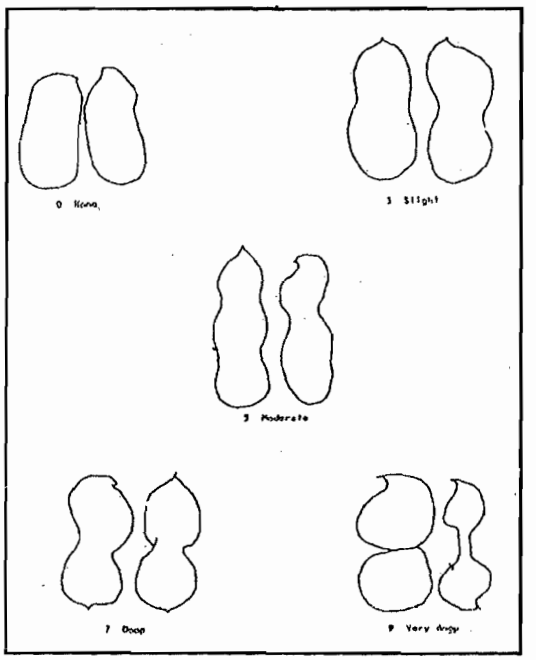

Fig. 2b. Pod constriction types in groundnuts.

TABLE 5

Beakiness (BNESS), Constriction (CONST.) of Pods, and Means and Ranges for Pod Length and Width of 17 Accessions of Groundnuts Studied

			Pod length		*Pod width*	
Accession	*BNESS*	*CONST.*	*Mean (cm)*	*Range (cm)*	*Mean (cm)*	*Range (cm)*
87/13	Mod	Slight	23.54 ± 0.22	15.10 - 27.45	11.78 ± 0.09	10.87 - 12.05
87/21	Slight	Mod	24.34 ± 0.23	18.97 - 27.85	10.96 ± 0.05	8.96 - 11.98
87/22	Mod	Mod	26.62 ± 0.16	22.10 - 29.10	11.72 ± 0.09	9.80 - 13.60
87/26	Slight	Slight	21.07 ± 0.23	14.75 - 25.25	12.10 ± 0.05	10.95 - 13.56
87/28	Mod	Mod	22.30 ± 0.45	15.98 - 26.54	12.86 ± 0.01	10.97 - 13.98
87/31	Slight	Slight	23.13 ± 0.18	15.10 - 28.00	11.73 ± 0.05	9.85 - 12.90
87/36	Slight	Deep	25.26 ± 0.21	18.95 - 28.85	10.88 ± 0.03	9.85 - 12.90
87/42	Slight	Slight	31.30 ± 0.16	28.35 - 35.00	15.48 ± 0.09	14.65 - 16.76
87/54	Slight	Deep	26.42 ± 0.30	19.10 - 33.25	10.58 ± 0.01	9.80 - 11.10
87/65	Slight	Slight	25.36 ± 0.75	17.20 - 30.60	11.67 ± 0.04	10.35 - 13.75
87/82	Absent	Slight	23.71 ± 0.72	15.70 - 30.60	12.10 ± 0.06	10.70 - 13.56
87/84	Absent	Slight	24.98 ± 0.71	16.95 - 30.08	12.85 ± 0.02	10.80 - 13.96
87/114	Slight	Slight	25.13 ± 0.51	17.88 - 28.40	11.82 ± 0.07	10.95 - 12.87
87/127	Slight	Mod	23.78 ± 0.65	16.40 - 30.55	10.00 ± 0.07	8.85 - 11.10
87/128	Mod	Deep	17.86 ± 0.45	18.10 - 30.45	11.91 ± 0.06	10.40 - 13.87
87/154	Mod	Mod	35.32 ± 0.41	20.50 - 50.30	12.35 ± 0.11	11.15 - 13.87
87/168	Slight	Mod	26.00 ± 0.47	19.90 - 30.00	12.02 ± 0.01	10.15 - 14.50
CV			15.29 %		9.90 %	

Key: Mod = Moderate

produced the shortest. The widest pod was produced by accession 87/42 and the narrowest by accession 87/127. The CV for pod width was 9.9 per cent. There was a positive correlation between pod length, or pod width and yield (r = 0.29 and 0.20, respectively). These values were not significant.

Variation in seed characteristics

Table 6 shows the means and ranges for the lengths and widths of the seeds produced by the accessions. The length of the seeds ranged from 9.96 to 17.70 mm. Accession 87/54 had the highest mean value whilst accession 87/127 had the lowest.

TABLE 6

Means, Ranges of Seed Length and Width, and Seed Colour of 17 Accessions of Groundnuts Studied

Accession	*Seed length*		*Seed width*		*Colour*
	Mean	*Range*	*Mean*	*Range*	
87/13	13.45 ± 0.06	11.23 - 15.42	8.97 ± 1.6	6.86 - 9.97	brown
87/21	11.98 ± 0.06	9.96 - 14.97	9.56 ± 1.5	6.98 - 10.76	brown
87/22	12.81 ± 0.03	12.0 - 13.65	8.68 ± 1.3	8.00 - 9.30	light brown
87/26	12.03 ± 0.02	11.50 - 12.30	9.78 ± 1.6	9.40 - 10.00	brown
87/28	12.45 ± 0.05	10.98 - 12.96	9.65 ± 1.7	9.06 - 10.89	variegated
87/31	12.52 ± 0.10	11.50 - 14.90	9.32 ± 1.7	8.60 - 10.20	brown
87/36	12.35 ± 0.04	11.10 - 12.85	9.48 ± 1.7	7.60 - 10.50	light brown
87/42	14.93 ± 0.10	13.15 - 17.10	10.40 ± 1.9	10.00 - 10.95	brown
87/54	15.80 ± 0.04	15.25 - 16.85	8.51 ± 1.5	7.85 - 9.40	light brown
87/65	14.13 ± 0.07	12.75 - 16.30	10.47 ± 1.9	9.40 - 11.35	light brown
87/82	14.01 ± 0.06	13.80 - 15.50	9.53 ± 1.7	9.05 - 10.00	light brown
87/84	13.25 ± 0.12	11.98 - 14.86	9.90 ± 1.3	8.78 - 11.02	light brown
87/114	15.60 ± 0.16	14.80 - 16.45	8.57 ± 1.2	7.90 - 9.65	light brown
87/127	11.65 ± 0.24	11.15 - 12.45	9.28 ± 1.9	8.80 - 9.60	light brown
87/128	15.13 ± 0.10	13.30 - 19.15	9.88 ± 1.7	9.05 - 10.65	brown
87/154	15.21 ± 0.08	14.60 - 16.35	7.85 ± 1.5	6.65 - 8.40	light brown
87/168	14.43 ± 0.07	12.55 - 15.50	10.26 ± 1.4	9.65 - 10.95	light brown
CV	10.11		7.61		

For the width of seeds, the range was between 6.65 and 10.47 mm. The CVs for both characters were low, 10.11 and 7.61 per cent, respectively. Three types of seeds were observed for seed colour. While 10 accessions were light brown, six were brown, and one was variegated. For seed yield, the range was from 61.11 g/m^2 for accession 87/26 to 195 g/m^2 for accession 78/42. The CV for this character was 21.46 per cent (Table 7). For 100-seed weight, the range was between 3.0 and 7.0 g. The CV was 20.48 % (Table 7).

Allozyme variation in 17 accessions of groundnuts

The three isozymes analyzed, esterase (*Est*), peroxidase (*Pero*) and acid phosphatase (*Acph*), showed variations among the accessions (Fig. 3a and b). Altogether, 19 bands were resolved. Five bands resolved by *Est*; one was monomorphic and four were polymorphic. Five groups of accessions can be distinguished by using the *Est* banding patterns (Fig. 3a). The first group comprising accessions 87/21, 87/42, 87/82, 87/84 and 87/168 had only one band. The banding patterns of the other groups comprised two or more bands. None of the accessions showed all the possible five bands (Table 8). The isozyme, *Pero*, identified 10 phenotypes. Each phenotype showed at least three of 11 bands. Three of the bands were monomorphic and migrated to the cathode. Among the 10 groups observed, there were eight one-accession groups. Accessions

TABLE 7

Means of Seed Yield per Plant and 10-Seed Weight of 17 Accessions of Groundnuts Studied

Accession	*Seed yield (g/m²)*	*10-seed weight*
87/13	120.65	5.5
87/21	135.60	5.6
87/22	134.02	5.2
87/26	61.11	4.7
87/28	140.94	5.0
87/31	124.44	5.2
87/36	106.67	5.5
87/42	195.00	6.5
87/54	175.56	4.5
87/65	163.33	6.0
87/82	155.55	4.5
87/84	145.90	6.0
87/114	148.88	6.0
87/127	153.66	3.0
87/128	132.38	7.0
87/154	177.76	5.2
87/168	138.88	6.0
CV	21.5%	20.5%

87/13, 87/42, 87/54, 87/65 and 87/82 had only the three cathodal bands, whilst accessions 87/22, 87/26, 87/28 and 87/114 showed four other bands besides the monomorphic bands. The isozyme, *Acph*, exposed the least variation. Only three bands were observed, one of which was monomorphic. The accessions fell into three distinct groups; two of the groups were one-accession groups whilst the rest showed the same pattern. Chi-square tests to determine associations between allozymes and morphological characters were not significant.

Discussion

The study showed very low variation for the quantitative characters, which were also not significantly correlated with yield. This was evident in the low coefficient of variations for all of the characters. This low variation in quantitative characters suggests that any breeding effort aimed at improving such characters may not be successful unless accessions with diversity for such characters are included in the programme.

TABLE 8

Phenotypes of the 17 Accessions of Groundnuts Considering Growth Habit, Pigmentation of the Stem, Stem Branching Patterns, Beakiness of the Pod, Constriction of the Pod, and Colour of the Seed in that Order

Accession	*Phenotype*
87/13	D-3; (-); IW; moderate; slight; brown
87/21	D-3; (-); IO; slight; moderate; brown
87/22	D-3; (-); IO; slight; moderate; brown
87/26	D-1; (+); S; slight; slight; brown
87/28	D-3; (+); IW; moderate; moderate; brown
87/31	D-1; (+); IO; slight; slight; brown
87/36	D-2; (-); S; slight; deep; light brown
87/42	D-3; (-); IO; slight; slight; brown
87/54	Erect; (-); A; slight; deep; light brown
87/65	D-1; (+); IW; slight; slight; light brown
87/82	D-2; (-); IO; absent; slight; light brown
87/84	D-2; (-); A; absent; slight; light brown
87/114	D-3; (-); A; slight; slight; light brown
87/127	D-2; (+); S; slight; moderate; light brown
87/128	D-3; (-); A; moderate; deep; brown
87/154	D-2; (+); IW; moderate; moderate; light brown
87/168	D-2; (+); S; slight; moderate; light brown

Key: D = Decumbent; S = Sequential; A = Alternate
IW = Irregular with flowers on the main stem
IO = Irregular without flowers on the main stem
(-) = Absence of pigmentation
(+) = Presence of pigmentation

Information on genetic relatedness among germplasm is useful not only for the selection of parents for a breeding programme, but also for the conservation of germplasm (Gill, 1985). Using each of the six morphological markers, it was possible to put the 17 accessions into various groups. Considering all of the six characters, the 17 accessions fell into 15 one-accession groups. The remaining two accessions, 87/127 and 87/168, showed the same characters for all of the six morphological markers studied. A similar picture emerged from the isozyme studies. Each isozyme could be used to group the accessions.

The isozyme, *Acph* showed the most variation whilst *Pero* showed the least. Taking three

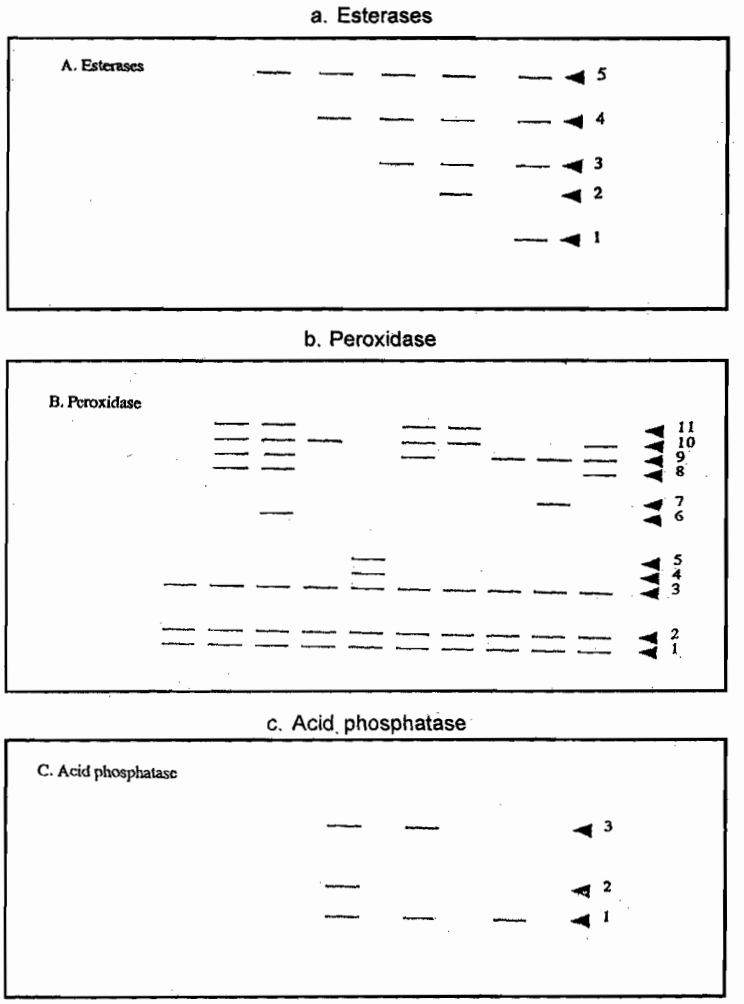

Fig. 3. Isozyme banding patterns observed in the 17 accessions for the three isozymes studied.

isozymes together, it was possible to separate the 17 accessions into 15 distinct groups; 13 of which were one-accession groups while the remaining two contained two accessions each (87/42 and 87/82 in one group, and 87/54 and 87/65 in the other). The lack of association between the results of the morphological and isozyme studies is not unexpected. It is possible that these markers sampled different portions of the genome. Despite the seeming effective use of morphological markers in the characterization of the accessions in comparison with the isozyme markers, these markers have ambiguous and indirect correspondence with genotype as multiple genotypes give phenotypes of similar outward appearance, making it difficult to determine the extent to which similar phenotypes reflect similar genotypes. Additionally, they are influenced by the environment to varying degrees, and an entirely different phenotype could be expressed under different conditions. Isozyme markers overcome this problem (Smith & Smith, 1992) because they have a simple relationship with the genotype of an organism and are uninfluenced by the environment. In addition, the method is quick and cheaper than DNA-based methods.

Although it was impossible to find significant associations between allozymes and morpho-agronomic traits, several workers have observed close linkages between allozymes and agronomically important traits (Rick & Fobes, 1974; Hunt & Barnes, 1982; Weeden, 1984). The detection of such linkages could potentially facilitate the transfer of economically important traits from one accession to another. Finally, the results of the study show that isozyme markers are very useful in characterizing accessions of groundnuts.

The authors are currently studying all of their genetic resources of groundnut using molecular markers to identify tags for disease resistance and other economically important genes. In the

quest for new genetic resources of crop plants, such screening will probably play an increasing role not only for plant breeding and genetic conservation, but also in the formulation of optimal sampling strategies as well as contribute to the biological understanding of the genetic structure of populations.

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