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Germplasm collection and morphological characterization of local accessions of tigernut (*Cyperus esculentus* L.) in Ghana for conservation and utilization

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Tigernut (*Cyperus esculentus* L.) is a nutritious crop of the sedge family. In Ghana available local accessions have not been collected and characterized for conservation and utilization purposes. The objective of this study was to collect, conserve and characterize twenty-four local accessions of tigernut in Ghana based on agro-morphological traits. The ANOVA revealed significant ($p<0.05$) differences among the accessions for all the traits studied except for hundred nut weight, indicating the presence of sufficient variability among the accessions. The hierarchical cluster analysis put the accessions into six major groups confirming a wide range of diversity among the accessions. The biplot of the principal components analysis revealed the scattering of the accessions in all the quarters which further suggest a higher level of variability among the accessions studied. The PCA also revealed that the first five PC accounted for a total of 88.4% variability among the accessions. PC1 accounted for 45.6% of the total variation with an Eigenvalue of 6.84. The correlation analysis among the traits showed significant and positive correlation between number of nuts and good nuts (r=0.94) and detached nuts and attached nuts. However, there was significant negative correlation among nut width and detached nuts (r = - 0.88) and harvest index and biological yields (r = - 0.77). Based on the study, accessions TPY, CCB, BB, DY, ADL, KB, KAY, WY1 and BKB which recorded high values for number of nuts, good nuts, nut length, nut width and harvest index could be included in breeding programs for varietal development of tigernut in Ghana.

Key words: Tigernut, *Cyperus esculentus*, Ghana, morphological characterization, cluster analysis, germplasm, principal component analysis, correlation, variability.

INTRODUCTION

Tigernut belongs to the family *Cyperaceae*, and produces rhizomes from the base and tubers that are somewhat spherical (Cortés et al., 2005). The plant is not really a nut but a tuber which was first discovered some 4000

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years ago (Lowe et al., 2000). It has other names like yellow nutsedge, chufa, flat sedge, rush nut, water grass, earth almond, northern nut grass and nut grass (Shilenko et al., 1979). The tubers are very nutritious, typically, hundred grams of the nuts contain 386 kcal (1635 kj) of energy, 7% proteins, 26% fats (oils), 31% starch, 21% glucose and 26% fibre of which 14% is non-soluble and 12% soluble (Burden, 2003). It also contains vitamins A, B1, D2 and E, while the minerals include, Calcium, Magnesium, Sodium, Potassium, Copper, Iron and other beneficial enzymes (Burden, 2003). Tigernut is used as a source of food, medicine and perfumes (De Vries, 1991). It can be eaten raw, roasted, dried, baked or made into a refreshing beverage called Horchata De Chufas or tigernut milk which is very nutritive.

Medically, the nuts are reported to be aphrodisiac, carminative, diuretic, stimulant and tonic which can be used in the treatment of constipation, high blood pressure and diarrhoea (Oladele and Aina, 2007). Economically tigernuts provides Ghana with foreign exchange through its exportation. In 2010 Ghana exported 63,462 tonnes of tigernut valued at US$ 25,130.82 to countries such as England, Japan and America (GEPC, 2010). Its cultivation also provides jobs to about 85% of the youth and women in the major growing areas of Ghana (Tetteh and Ofori, 1998). In spite of the nutritional, medicinal and economic value of tigernut, the crop still remains an orphan.

Research into the production and general improvement of tigernut through breeding has received very little attention and farmers still cultivate landraces which are low yielding and susceptible to diseases and pest. Available accessions of tigernut in Ghana have not yet been collected, characterized and conserved. This further exposes available landraces to erosion of their genetic resources and limits breeding of improved varieties. Germplasm characterization plays an important role in varietal development of crops as genotypes with desirable traits are identified and utilized in the crop improvement programmes. Knowledge on the genetic diversity and variation among available accessions is very important for pragmatic use of plant genetic resources and also to determine evolutionary relationships (Zada et al., 2013). It will also aid in the early identification and exploitation of desirable traits such as high yield and early maturity. The existence of genetic variation among accessions can be employed as the basis for improving yield and other potentials of crop plants (Makinde and Ariyo, 2013).

Morphological attributes of crops have been employed as characterization tools among crops such as clusterbean (Manivannan et al., 2016), groundnut (Makinde and Ariyo, 2013), cowpea (Manggoel et al., 2012). Morphological traits has also been used to determine the extent of genetic variation among purple and yellow nut sedge accessions (Cruz and Baltazar, 2001, Peña-Fronteras et al., 2009, Okoli et al., 1997, Casimero et al., 1999). Before any effective work can be done on tigernut, there is the need to collect and characterize the local accessions that are available in Ghana. The objective of this study was to collect and characterize the accessions of tigernuts available in Ghana to promote their conservation and utilization.

MATERIALS AND METHODS

Study area

The study was conducted at the multipurpose nursery of the College of Agriculture, University of Education, Winneba Mampong-Ashanti, during the minor season growing season. Mampong-Ashanti lies within longitude 0°05"W and 1°30"W and latitude 6°55"N and 7°30"N and altitude 395 m above sea level. The area has an average annual rainfall of 1270 mm in two seasons (March and September) and a mean daily temperature of 27°C (Metrological Service, Mampong, 2010).

Germplasm collection

Twenty-four accessions of tigernut were collected from six major tigernut growing regions in Ghana that is Eastern region (Asukese Donkokrom, Nkwakwa), Volta region (Krachi), Upper East region (Bawku), Upper West region (Wa), Central region (Kasoa, Badwiase, Gomoa Feteh, Twifo Praso) and Brong Ahafo (Techiman). Table 1 shows the names, colour and collection area of the accessions. The accessions collected were kept in polyethylene bags and tagged with their names. The accessions were named using the first letters of the towns where they were collected and the colour of the nuts. Numbers were used to differentiate accessions from the same town which were having the same colour for example WY1 meaning Wa Yellow, first accession. Figure 1 shows the map of Ghana showing the location of regions and the towns where the accessions were collected. Figure 4 shows the pictures of some of the accessions collected.

Germplasm evaluation

The accessions were evaluated using RCBD with five replications in plastic buckets. The volume of the bucket was 12212 cm^3 and was fully filled with heat sterilized sandy loam soil. The buckets were arranged 50 cm within rows and 100 cm between rows. Each bucket contains five stands of tigernut per genotype. The five stands were arranged 5 cm within rows and 5 cm between rows in the buckets. The plants were raised under irrigation and manual weeding was done regularly in the buckets as well as between and within the rows of the arranged buckets. Data was collected on all the five stands in the buckets. Data collection was started when the plants were a week old. There was no fertilizer and pesticide application. The following traits were evaluated; percentage germination, number of tillers/stand, number of attached nuts/stand, number of detached nuts / stand, number of good nuts/stand, number of bad nuts /stand, total nuts /stand, number of leaves/ plant, number of ridges /nuts, nut length and width (cm), hundred nut weight, economic yield, biological yield and Harvest index (%).

Statistical analysis

The data collected was subjected to Analysis of Variance (ANOVA) using the GenStat statistical software, version 11.1 (GenStat, 2008).

Dissimilarity matrix based on Euclidean distance was estimated using GenStat 11.1 version. The scores of the dissimilarity matrix

Table 1. Source and colour of accessions collected.

S/N	Accessions	Collection place/area	Region	Colour
1	ADS	Asukese Donkorkrom	Eastern	Yellow
2	KB	Krachi	Volta	Black
3	KY	Krachi	Volta	Yellow
4	KAB	Kwanyako	Central	Black
5	KAY	Kwanyako	Central	Yellow
6	WY 1	Wa	Upper West	Yellow
7	DY	Bodwiase	Central	Yellow
8	BB	Bawku	Upper East	Black
9	BY	Bawku	Upper East	Yellow
10	TY	Techiman	Brong Ahafo	Yellow
11	BLB	Badwiase	Central	Black
12	BLY	Badwiase	Central	Yellow
13	CCB	Kasoa	Central	Black
14	CCY	Kasoa	Central	Yellow
15	AY	Nkwakwa	Eastern	Yellow
16	TPB	Twifo Praso	Central	Black
17	TPY	Twifo Praso	Central	Yellow
18	BKB	Badwiase	Central	Black
19	WY2	Wa	Upper West	Yellow
20	BKY	Badwiase	Central	Yellow
21	WB	Wa	Upper West	Black
22	GFB	Gomoa Fetteh	Central	Black
23	GFY	Gomoa Fetteh	Central	Yellow
24	ADL	Asukese donkokrom	Eastern	Yellow

ADS (Asukese Donkorkrom Short), KB (Krachi Black), KY (Krachi Yellow), KAB (Kwanyaako Asamoahkrom Black), KAY (Kwanyaako) Asamoahkrom Yellow), WY1 (Waa Yellow 1), DY (Danso Yellow), BB (Bawku Black), BY (Bawku Yellow), TY (Techiman Yellow), BLB (Badwiase Local Black), BLY (Badwiase Local Yellow), CCB (Cape Coast Black), CCY (Cape Coast Yellow), AY (Aduamoah Yellow), TPB (Twifo Praso Black), TPY (Twifo Praso Yellow), WY2 (Waa Yellow 2),BKB (Bawjiase Kwahu Black), BKY (Bawjiase Kwahu Yellow), WB (Waa Black), GFB (Gommoa Fetteh Black), GFY (Gommoa Fetteh Yellow), ADL (Asukese Donkokrom Short).

were used to perform a hierarchical cluster analysis (Ward, 1963). Principal Component Analysis (PCA) based on the traits was performed to find out the relative contribution of the different traits to the total variation in tigernut. A biplot was drawn to show the relationship between the accessions and the traits using the Eigen values associated with the components versus the number of the component. Pearson (1901) Correlation coefficients was carried out for all the traits and a correlation matrix was prepared to understand the relationship among the different traits.

RESULTS

Variation in agronomic traits among the accessions

The Analysis of Variance (ANOVA) and its corresponding coefficient of variation (Table 2) revealed significant differences ($p<0.05$) among the accessions for all the traits studied except for hundred nut weight. Percentage germination ranged from 43.0 to 88.0% with accession KY recording the highest germination percentage and ADS recording the least. Accession CCB had the highest number of tillers per stand which ranged from 2.6 to 4.6 with accession GFY having the least number. For number of attached nuts per stand, accession BB showed the highest value with GFY recording the least value. The number of detached nuts per stand ranged from 3.80 to 22.0, accession BB was observed to have the highest and CCB had the least. Accessions CCB, KY and DY recorded the same number of bad nuts per stand of 5.6 which was the highest and accession BB had the least number of bad nuts per stand of 1.6. It can be observed in Table 6 that accession BB had a highest good number of nuts per stand (42), while ADL the lowest (4.80). For total number of nuts per stand Accession BB had highest number (43.0) while accession GFY had the least number (6.20). Accession GFY was observed to have the highest number of leaves per plant and accession DY the least. The Table clearly shows that, accession ADL had the longest nut length of 1.94cm among the accessions studied while accession BB had the shortest nut length of 0.70cm. Among the accessions studied, ADL demonstrated the highest hundred seed weight of 295.3g and accessions BB demonstrated the lowest of 17.8g.

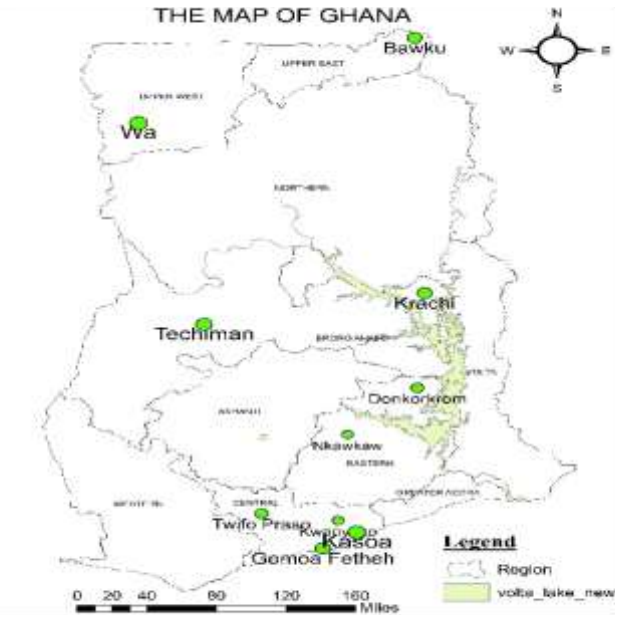

Figure 1. Map of Ghana showing the location of regions and the towns where the accessions were collected.

Table 2. Mean and the standard error of the agronomic traits for the accessions evaluated.

Accession	%Gem	NTS	ANS	DNS	BNS	GNS	TNS
ADS	43.00±2.55	3.40±0.24	7.80±0.97	10.20±1.11	4.40±0.40	15.00±1.58	18.20±1.62
KB	81.00±7.48	3.00±0.00	6.80±0.96	5.00±1.09	4.20±0.48	8.00±0.94	11.60±1.56
KY	88.00±6.44	2.80±0.20	4.60±0.40	9.00±1.34	5.60±0.60	9.20±1.20	12.40±1.56
KAB	73.00±5.15	2.80±0.20	5.40±0.67	4.20±0.58	2.80±0.58	9.20±0.97	13.40±1.69
KAY	83.00±7.18	2.60±0.24	4.60±0.81	7.20±0.91	4.80±0.80	8.20±0.86	15.00±1.51
WY	77.00±5.12	4.20±0.37	5.20±1.15	9.00±1.64	4.60±0.40	10.80±1.02	12.80±1.49
DY	48.00±8.00	4.00±0.45	11.80±1.06	12.60±1.69	5.60±0.74	17.40±1.66	22.00±1.04
BB	48.00±8.00	4.20±0.37	26.00±3.61	22.00±1.76	1.60±0.50	42.00±5.02	43.20±6.22
BY	48.00±6.44	3.40±0.25	8.60±1.02	19.20±2.85	3.80±0.48	2.60±3.31	26.20±3.07
TY	62.00±7.35	2.80±0.37	5.00±1.04	8.20±1.02	3.60±0.67	9.80±1.82	13.00±1.09
BLB	69.00±5.34	3.60±0.25	8.20±0.66	5.00±0.31	4.20±0.73	10.00± 1.89	12.20±2.13
BLY	68.00±8.46	2.80±0.37	4.80±0.96	8.00±1.37	5.40±0.74	8.60±1.03	12.40±1.50
CCB	75.00±5.70	4.60±0.40	7.60±0.50	3.80±0.58	5.60±1.16	8.00±0.83	12.00±0.00
CCY	81.00±2.92	3.00±0.55	4.00±0.44	8.40±1.93	2.80±0.48	8.60±1.20	10.40±1.16
AY	75.00±4.18	3.40±0.25	3.40±1.16	8.20±0.80	2.40±0.50	13.80±1.15	13.20±1.06
TPB	87.00±3.00	3.40±0.25	8.40±1.32	8.20±1.39	3.00±0.54	15.40±1.28	13.00±1.67
TPY	78.00±4.06	3.40±0.25	3.20±0.20	10.20±0.97	3.00±0.70	9.60±0.81	11.20±1.31
WY2	74.00±7.97	3.20±0.20	3.00±0.54	8.80±1.59	2.40±0.50	9.40±1.80	14.80±1.59
BKB	77.00±5.15	3.20±0.20	8.00±0.83	4.40±0.24	4.80±0.37	9.40±0.67	11.20±0.73
BKY	63.00±4.64	3.00±0.00	4.20±0.66	8.00±1.64	1.80±0.20	9.00±0.89	10.60±1.12
WB	65.00±4.47	2.80±0.37	6.60±0.97	5.40±1.07	2.00±0.54	10.00±1.14	11.80±0.97
GFB	80.00±5.00	3.20±0.20	6.60±0.81	6.00±0.83	4.00±0.44	8.80±0.73	12.20±0.97
GFY	66.00±4.85	2.40±0.25	1.80±0.20	4.60±0.40	2.00±0.44	4.80±0.37	6.20±0.73
ADL	50.00±6.52	3.00±0.32	2.20±0.20	6.00±0.63	1.80±0.37	7.60±0.81	8.80±0.80
LSD (5%)	16.03	0.85	0.43	3.04	3.18	1.58	5.14
CV%	18.50	20.70	20.70	36.90	30.20	35.00	28.20

%Gem= percentage germination, NTS=number of tillers /stand, ANS= number of attached nuts / stand, DNS= number of detached nuts /stand, BNS= number of bad nuts / stand, GNS= number of good nuts /stand, TNS= total number of nuts / stand.

Table 2. Contd.

Accession	NL	NW	NRN	100SW	EY	BY	HI
ADS	1.38±0.06	1.12±0.05	3.00±0.0	90.7±4.69	1.91±0.34	5.27±0.51	35.34±4.26
KB	1.68±0.06	1.32±0.05	3.80±0.20	129.0±7.55	1.70±0.11	5.14±0.37	33.89±3.67
KY	1.14±0.02	1.14±0.06	3.00±0.00	76.1±4.50	2.52±0.10	4.55±0.19	55.59±1.40
KAB	1.52±0.05	1.24±0.05	3.80±0.20	113.7±6.76	2.55±0.13	3.77±0.17	67.74±0.72
KAY	1.58±0.13	1.02±0.03	3.00±0.0	89.7±6.20	2.72±0.30	4.76±0.55	57.56±2.89
WY	1.30±0.04	1.12±0.02	3.00±0.01	92.8±7.60	1.73±0.06	5.87±0.14	29.52±0.95
DY	1.20±0.01	1.10±0.03	3.40±0.24	97.3±4.60	2.13±0.20	5.53±0.62	39.03±3.15
BB	0.70±0.01	0.64±0.02	2.00±0.0	17.8±0.82	1.70±0.20	3.23±0.22	52.29±2.99
BY	0.86±0.02	0.78±0.02	2.00±0.01	29.7±0.69	2.47±0.29	4.18±0.35	58.41±2.51
TY	1.36±0.04	1.10±0.01	3.00±0.01	84.8±6.20	2.18±0.15	4.36±0.36	50.84±3.88
BLB	1.54±0.06	1.22±0.03	4.00±0.01	129.7±6.35	2.41±0.33	4.82±0.36	49.06±3.34
BLY	1.36±0.04	1.08±0.03	3.60±0.24	86.4±5.61	1.79±0.30	3.69±0.36	49.30±7.45
CCB	1.68±0.08	1.30±0.03	4.20±0.20	124.4±8.79	2.06±0.20	5.86±0.31	35.96±4.76
CCY	1.76±0.05	1.04±0.05	3.40±0.24	93.6±7.81	1.50±0.09	5.44±0.25	27.65±0.91
AY	1.40±0.06	1.16±0.0	3.20±0.20	103.3±3.95	1.50±0.08	3.78±0.29	39.94±1.32
TPB	1.40±0.05	1.20±0.0	3.80±0.20	113.9±7.25	2.10±0.26	4.32±0.20	47.97±3.97
TPY	1.76±0.08	1.02±0.0	3.40±0.24	102.7±3.24	1.73±0.16	3.50±0.18	49.13±2.75
WY2	1.32±0.03	1.14±0.0	3.00±0.01	97.1±4.64	1.62±0.14	5.44±0.31	29.59±1.27
BKB	1.40±0.03	1.16±0.0	3.80±0.20	101.1±4.24	1.79±0.13	2.73±0.19	65.88±2.99
BKY	1.74±0.10	1.08±0.0	3.60±0.24	117.5±9.11	1.79±0.08	4.53±0.35	39.95±1.56
WB	1.46±0.05	1.22±0.0	4.00±0.01	132.3±7.85	1.93±0.15	3.43±0.16	56.43±3.92
GFB	1.44±0.02	1.22±0.03	3.40±0.24	99.3±4.86	1.98±0.19	3.67±0.29	54.27±3.8
GFY	1.58±0.04	1.10±0.03	3.60±0.24	95.6±6.04	2.16±0.03	4.87±0.27	45.15±3.01
ADL	1.94±0.09	1.04±0.06	3.40±0.24	295.3±5.94	2.13±0.08	3.76±0.18	57.25±3.17
LSD (5%)	0.18	0.12	0.48	119.26	0.56	0.91	9.39
CV%	9.8	8.10	11.50	ns	22.10	16.30	15.90

NL= nut length, NW= nut width, NRN= number of ridges/ nut, 100sw= hundred seed weight, EY= economic yield, BY= biological yield, HI= harvest index

The economic yield ranged between 2.73 and 1.50, with accession KAY having the highest and AY the least. The table revealed that accession WY1 had a biological yield of 5.87g which was the highest among the accessions and accession BKB the least of 2.73g. Accession KAB and CCY recorded harvest index of 67.74 and 27.65, respectively, which happened to be the highest and lowest. The significant differences among the accessions for the yield and yield related trait are a sign of the presence of high degree of genetic variations. This implies the great potential of the accessions for utilization in future breeding programmes.

Cluster analysis

The hierarchical cluster analysis based on the traits evaluated grouped the accessions into six groups (Figure 2). Table 3 shows the clusters, accessions in each cluster them. Table 4 shows the traits that defined each cluster. Cluster II consisted of the largest number of accessions (10) and were characterised by wide nuts and high number of ridges/nuts. Cluster III which had six accessions were characterized by high germination percentages. Cluster I and IV contained the same number of accessions (3) and were high yielding and had high number of tillers per stand.

Cluster V and VI which contain one accession each had high harvest index, economic yield and long nuts. All the groups contained accessions of diverse geographical origin and colour. Figure 4 shows variation in nut shape, size and colour clearly indicating the diversity among the accessions.

Principal component analysis

Variations among the traits were also assessed using principal components analysis (PCA) for the twenty-four

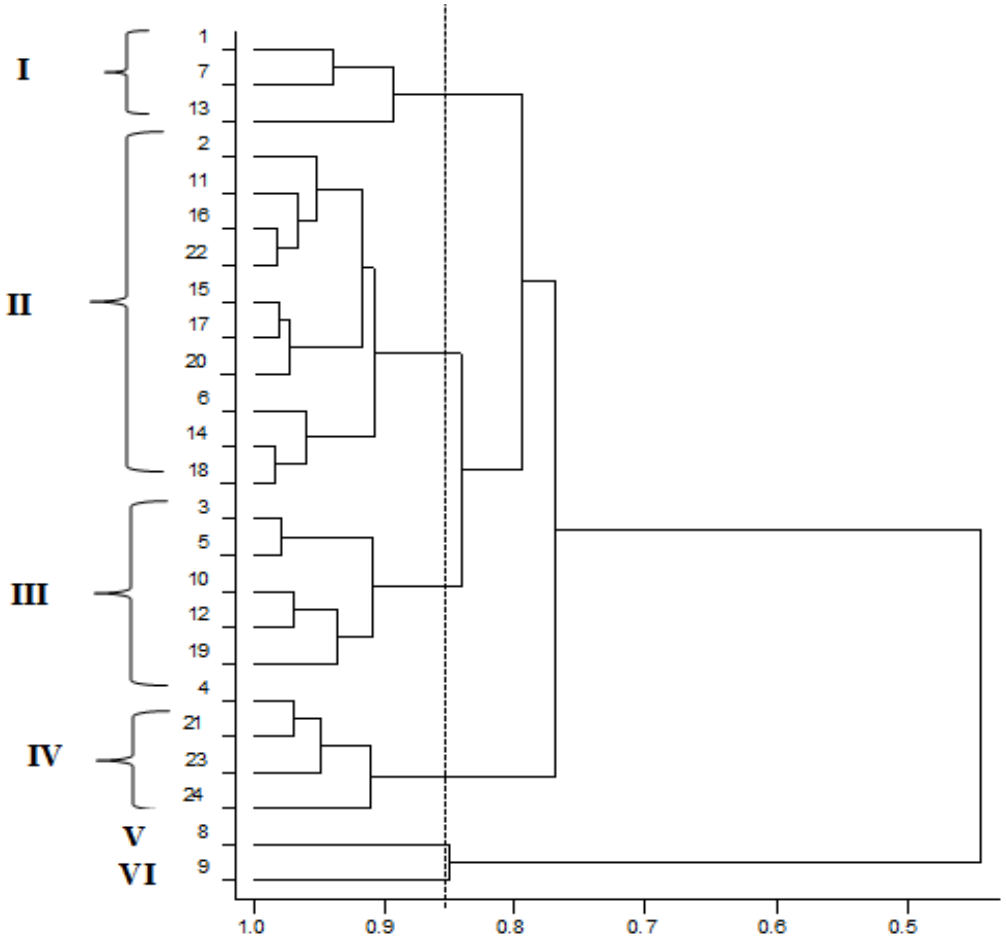

Figure 2. Dendrogram showing the genetic diversity among the twenty-four tigernut accessions in Ghana.

Table 3. Clustering of accessions based on the qualitative traits.

Cluster	Number of accessions	Accessions
1	3	ADS, DY, CCB
2	10	KB, BLB, TPB, GFB, AY, TPY, BKY, WY, CCY, BKB
3	6	KY, KAY, TY, BLY, WY2, KAB
4	3	WB, GFY, ADL
5	1	BY
6	1	BB

accessions. The first five PC accounted for a total of 88.4% variability among the accessions (Tables 5 and 6). PC1 recorded an eigenvalue of 6.8 which explained 45.6% of the entire variation with total number of nuts/stand, number of good nuts/stand and number of detached number of nuts/stand contributing greatly to the variation for this PC. PC2 explained 16.4% of the variation with the eigenvalue of 24.5. PC3, PC4 and PC5 explained 11.1, 8.3 and 7.0%, respectively of the total variation with eigenvalues of 1.66, 1.24 and 1.05, respectively. The biplot which separated the accessions based on PC1 and PC2 shows the accessions scattering

Table 4. Means of the agronomic traits for the six clusters of twenty-four tigernut accessionsin Ghana.

Trait	Cluster						Average
	1	2	3	4	5	6	
% Germ	45.50	70.60	76.36	48.00	48.00	50.00	69.13
TS	3.70	3.40	3.09	4.20	3.40	3.00	3.26
AN S	9.80	6.68	4.86	26.00	8.60	2.20	6.58
DNS	11.40	5.44	7.46	22.00	19.20	6.00	8.40
BNS	5.00	3.56	3.66	1.60	3.80	1.80	3.59
GNS	16.20	9.00	9.69	42.00	22.60	7.60	11.88
TNS	20.10	11.84	12.23	43.20	26.20	8.80	14.53
LP	8.30	7.08	7.01	9.00	7.40	7.60	7.26
NL	1.29	1.62	1.45	0.70	0.86	1.94	1.44
NW	1.11	1.23	1.12	0.64	0.78	1.04	1.11
RN	3.20	3.92	3.36	2.00	2.00	3.40	3.35
HSW	94.00	126.58	96.44	17.80	29.70	295.30	104.74
EY	2.02	1.98	1.99	1.71	2.47	2.14	2.01
BY	5.41	4.76	4.34	3.23	4.19	3.76	4.44
HI	37.19	43.06	47.87	52.29	58.41	57.25	46.99

Table 5. Principal component analysis of the agronomic traits of twenty four accessions of tigernut in Ghana.

Principal component	Eigen value	Proportion	Cumulative
1	6.8468	0.456	0.456
2	2.4538	0.164	0.620
3	1.6602	0.111	0.731
4	1.2419	0.083	0.814
5	1.0504	0.070	0.884
6	0.5767	0.038	0.922
7	0.4170	0.028	0.950
8	0.2810	0.019	0.969
9	0.1937	0.013	0.981
10	0.1247	0.008	0.990
11	0.0647	0.004	0.994
12	0.0551	0.004	0.998
13	0.0164	0.001	0.999
14	0.0121	0.001	1.000
15	0.0052	0.000	1.000

in all the quarters and association between traits and accessions (Figure 3). Nuts width, number of ridges/nuts, Percentage germination, nut length and hundred nut weights were associated with accessions KB, GFY and ADL were grouped. Attached nuts/stand, good nuts/ stand, total numbers of nuts/stand and detached nuts/ stand were also associated with accessions BB, ADS and DY.

Correlation among the agronomic traits

Pearson correlation was employed among the traits. The highest significant and positive correlation was observed between total number of nuts/ stand and good nuts/stand (r =0.94) (Table 7). Highly significance and positive correlation was also observed between detached nuts/ stand and attached nuts/ stand (r =0.90), total number of

Table 6. The first five principal components of the agronomic traits.

TRAIT	EIGEN VECTOR				
	PC1	PC2	PC3	PC4	PC5
% Germination	0.216	-0.030	0.248	-0.352	-0.442
NTS	-0.176	-0.439	-0.025	0.264	-0.200
ANS	-0.319	-0.032	0.037	0.245	-0.346
DNS	-0.364	-0.001	-0.036	-0.132	0.142
BNS	0.030	-0.201	0.633	0.209	-0.013
GNS	-0.366	0.017	-0.072	0.052	-0.162
TNS	-0.372	0.004	0.020	0.070	0.066
NLP	-0.252	-0.204	-0.065	0.402	0.039
NL	0.317	-0.058	-0.275	0.157	0.097
NW	0.316	-0.155	0.153	0.136	-0.249
NRN	0.306	-0.078	-0.015	0.314	-0.342
100SW	0.227	0.036	-0.350	0.480	0.185
EY	0.023	0.302	0.488	0.262	0.407
BY	0.059	-0.510	0.185	-0.082	0.434
HI	-0.022	0.580	0.174	0.262	-0.124
Eigen Value	6.8468	2.4538	1.6602	1.2419	1.0504
% Variability	45.6	16.4	11.1	8.3	7.0
% Cumulative	45.6	62.0	73.1	81.4	88.4

nuts/stand and attached nuts/stand (r = 0.89), nut length and total nuts / stand (r = 0.79) and number of ridges/ nut and nut width (r = 0.84). Negative significance correlation was also observed among nut width and detached nuts / stand (r = - 0.88), and harvest index and biological yield (r = - 0.77) (Table 7)

DISCUSSION

The significance differences (<0.05) among the accessions for the agronomic traits is a sign of the presence of high degree of genetic variation. This provides the plant breeder the opportunity to select the best accession for utilization in future breeding programs. Accessions such as BB, ADL, BY and BKB which had high good nut/stand, total nuts/stand, economic yield and harvest index respectively could be included in breeding programmes for varietal development of tigernut. The observed variability could be attributed to the genetic differences among the accessions. Variation in morphological traits among yellow nut sedge and purple nut sedge biotypes has been reported by Tayyar et al. (2003), Bhowmik (1997) and Wills (1998) also reported considerable heterogeneity in morphological among *Cyperus rutundus* populations from around the world.

The clustering of the accessions in the six major groups is an indication of diversity among the accessions of tigernut in Ghana. The grouping of the accessions from same origin and colour into different clusters suggests diversity among accessions within a geographical origin and among accessions beyond geographical origin.

Tayyar et al. (2003), Okoli et al. (1997) and Abad et al. (1998), reported on similar clustering of nutsedge populations on the basis of morphological traits.

The biplot also shows relationship between the accessions and traits evaluated. The observation of the accessions in all the quarters of the biplot suggests a high level of genetic diversity in the accessions evaluated. Concentration should be on the traits that defined PC1 for varietal development of tigernut. Divergence among the purple nutsedge accessions for the morphological traits has been reported by Holt (1994) and Tayyar et al. (2003).

Correlation among traits provides information on the nature and level of association between two pairs of traits and it could be possible to improve a trait by the selection of the other pair. The correlation analysis shows significance association among the traits studied which suggest that they can be predicted by using the other. Therefore, traits that showed significance and positive correlation in this study could be improved simultaneously while those that showed negative association will have to be improved independently.

Table 7. Correlation matrix among the agronomic traits for the twenty-four tigernut accessions at 5and 1% probability.

Characters	%G	NTS	ANS	DNS	BNS	GNS	TNS	NLP	NL	NW	NRN	100SW	EY	BY	HI
%G	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NTS	-0.19	1	-	-	-	-	-	-	-	-	-	-	-	-	-
ANS	-0.41	0.55	1	-	-	-	-	-	-	-	-	-	-	-	-
DNS	-0.53	0.38	0.67***	1	-	-	-	-	-	-	-	-	-	-	-
BNS	0.20	0.22	-0.01	-0.12	1	-	-	-	-	-	-	-	-	-	-
GNS	-0.51	0.49	0.90***	0.09	-0.19	1	-	-	-	-	-	-	-	-	-
TNS	-0.53	0.47	0.89***	0.89***	-0.08	0.94***	1	-	-	-	-	-	-	-	-
NLP	-0.50	0.53	0.60**	0.59**	0.17	0.58	0.64***	1	-	-	-	-	-	-	-
NL	0.32	-0.29	-0.68***	-0.77***	-0.14	0.77***	0.79***	-0.37	1	-	-	-	-	-	-
NW	0.52	-0.14	-0.52	-0.88***	0.29	-0.74***	-0.75***	-0.47	0.56***	1	-	-	-	-	-
NRN	0.41	-0.14	-0.41	-0.87***	0.12	-0.68***	-0.72***	-0.37	0.71***	0.84***	1	-	-	-	-
100SW	-0.02	-0.17	-0.45	-0.58***	-0.21	0.51	0.56**	-0.15	0.73***	0.42	0.53	1	-	-	-
EY	0.03	-0.27	-0.06	-0.07	0.30	-0.10	-0.01	-0.17	-0.09	0.01	-0.04	0.02	1	-	-
BY	-0.06	0.38	-0.19	-0.01	0.33	0.24	-0.15	0.05	0.15	0.26	0.07	-0.02	0.02	1	-
HI	0.05	0.03	0.12	-0.01	0.03	0.08	0.09	-0.14	-0.16	-0.17	0.03	0.05	0.59**	-0.77***	1

=Significant At P<0.005, * = Significant At P<0.001 %G = Percentage Germination, NTS = Number Of Tillers/ Stand, ANS = Attached Nuts / Stand, DNS = Detached Nuts / Stand, BNS Bad Nuts / Stand, GNS = Good Nuts /Stand, TNS = Total Number Of Nuts /Stand, NLP = Number Of Leaves/ Plant, NL = Nut Length, NW = Nut Width, NRN = Number Of Ridges/Nut, 100SW = 100 Seed Weight, EY = Economic Yield, BY = Biological Yield, HI = Harvest.

Conclusion

The study was conducted to characterized twenty-four tigernut accessions based on yield and yield related traits. The data shows that there exists a wide range of diversity among the accessions for the traits studied. This should help provide necessary information for the breeding of improved tigernut varieties in Ghana. Promising accessions such as TPY, CCB, BB, DY, ADL, KAY, WY1 AND BKB which recorded high values for the yield and yield related traits should be included in breeding programmes for varietal development of tigernut in Ghana. Also the diverse forms of the accession studied should be conserved at the gene bank in Ghana.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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