Available online www.jsaer.com

***Journal of Scientific and Engineering Research*, 2017, 4(10):91-101**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Genetic Affinity and Breeding Potential of Phenologic Traits of Acha (fonio) in Nigeria

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Abstract The evaluation of the phylogenetic diversity of Acha (*Digitaria sp.*) was carried out among thirty accessions collected from Tafawa Balewa Local Government Area (LGA) in Bauchi State; six LGAs of Plateau State and Jaba LGA of Kaduna State and assessed during the cropping seasons of 2012, 2013 and 2014 for their degree of relatedness. The randomized complete block design with three replications was employed for the morphological analyses. The phenotypic and genotypic characters for the different accessions revealed that the genotypes expressed variability in genetic diversity for the morphological traits. A high level of variability existed between the accessions with respect to plant height, stem girth, leaf length, leaf width, days to maturity and a 1000 seed weight. Principal component one (PC1) contributed 87.1%, 78.3 and 91.5% in 2012, 2013 and 2014 respectively of the total variation. Some of the accessions which were identified as *Digitaria iburua*, took the longest number of days to maturity and had the heaviest 1000 seed weight with an average at 0.72g. Those that were identified as *Digitaria exilis*, despite its early maturity date of an average of 132 days had an average 1000 seed weight of 0.62g. One of the accessions identified as *D. barbinodis* had the least number of days to maturity at 130 days and a mean 1000 seed weight of 0.51g. Correlation analyses revealed a highly significant and positive correlation between yield and the yield components. Dendrogram analyses across years show that two distinct clusters separated the accessions into two morphotypes: *Digitaria iburua* group and *D. exilis* group. *D. barbinodis*, a different species was found to be highly related to the *D. exilis* group. The traits in the 2012 planting season were separated between the 96.79 to 93.59%, this was observed to be between the 100 and 94.62% and, the 99 and 96% for 2013 and 2014 cropping seasons respectively, indicating that there were no traits that were 100% similar. The results study shows that the genotype had more variability in genetic diversity for plant height, leaf length, days to maturity and 1000 seed weight in the three-year field trials implying that selection for taller accessions, longer leaf length, wider stem girth and broader leaf width could lead to higher yields in Acha.

Keywords Genetic Affinity, Breeding Potential, Phenologic Traits, *Digitaria sp*

Introduction

Acha or Fonio crop also known as *Digitaria exilis* Kippis Stapf. L and *Digitaria iburua*is grown mainly in West and Central African regions [1]. It is sometimes considered as a small seed with a big promise and provides food early in the season when other crops are yet to mature for harvest [1]. The grains have been reported to be the tastiest and most nutritious of all the grains [1] and Temple and Bassa, [3] reported that it contains 7% crude protein, which is high in leucine (19.8%), methionine and cystine of about (7%) and valine (5%). It has also been reported to form the staple food in some of the producing areas in Nigeria where it is processed into various kinds of menus [4]. Production statistics in Nigeria reveal that about 70,000 metric tons of the crop is produced annually and the economic returns of Acha when computed showed that it is profitable to grow the crop compared to other crops like rice, sorghum and cowpea [5].

D. exilis is usually up to 80 cm tall while *D. iburua*, usually, can reach 1.5 m. Leaves are glabrous with a proximal sheathing base and distal strap shaped blade. Their inflorescence is a finger-shaped panicle having 2-5 digitate (*D. exilis*) or 4-10 sub-digitate (*D. iburua*) racemes of 5-12 cm length. In *D. iburua,* the lowest raceme is somewhat distant from the remaining. The spikelet contains two bisexual florets with the lower unfertile whilst the upper is fertile having three stamens with yellowish anthers, two lodicules and a pink or purplish stigma [6]. Within each species, diverse varieties with a growth cycle varying from 60 to 130 days are recognized by farmers [7].

This study therefore considered some morphological phenologic status of some accessions collected from some parts of Plateau state and environs to determine if differences exist in name, colour, size and even shape in the spectrum of collections from different areas of cultivation so as to determine the degree of relatedness of the accessions collected.

Materials and Methods

A field trial was carried out between May and November of 2008, 2009 and 2010 cropping seasons to investigate the morphological variations of some Acha accessions collected from different parts of Plateau, Bauchi and Kaduna states. The trial site Binkan, near Deeper Life Camp Ground, off Zaria road in Bassa Local Government Area of Plateau state, Nigeria is located at latitude 9.20^{o} N and longitude 8.90^{o} E of vthe equator at 1208 metres altitude above sea level, with a cool temperature which fluctuates between 13^{o} - 34.5^{o}C. The soil type is sandy loam with a past cropping history of maize, sorghum, Acha, millet, potatoes, soybeans cropped in no particular order. The thirty (30) accessions used in the experiment were obtained from different locations in Bauchi, Kaduna and Plateau states and laid out in 30 plots which measured 3m by 2m (6m^{2}) in a Randomised Complete Block design replicated three times with 1m inter replicate space and inter- and intra-row spacings of 100cm and 50cm respectively.

Land preparation was by ploughing and harrowing planting per plot was by broadcasting of 30g seed weight. Off plants (weeds) were rouged out 6weeks after planting and no fertilizer was applied. Weeding was subsequently sustained by manual removal of the weeds from the trials till harvest.

Field observations and data were collected on plant height, stem girth, number of leaves per plant, leaf length, leaf width, number of days to maturity and 1000 Seed weight. Data collected was subjected to the Analysis of Variance (ANOVA) and treatment means were separated to test for significance using the 'F' test as described by Snedecor and Cochran [8]. Significance of mean difference was tested using the Least Significant Difference (LSD) at 0.05 level of probability.

Simple correlation coefficient was also used to determine the relationship between 1000 seed weight and plant height, stem girth, leaf length, leaf width and number of days to maturity; plant height and stem girth, leaf length, leaf width and number of days to maturity; stem girth and leaf length, leaf width, number of days to maturity; leaf length and leaf width, number of days to maturity and; between leaf width and the number of days to maturity.

Principal Component Analysis (PCA) was also employed to further elucidate the contributions of variability among the different variables of the accessions, in which dendrograms were constructed to illustrate the level of identity and degree of relatedness among the various groups of the accessions.

Results and Discussion

The results for phenologic traits are presented in Tables 1 to 6 and shows that significant differences existed among the accessions with respect to plant height, stem girth, leaf length, leaf width, days to maturity and 1000 seed weight.

Table 1: Mean Height of 30 accessions in 2012, 2013 and 2014

		Plant Height (cm)		
Accession Code	**Accession Name**	**2012**	**2013**	**2014**
P1	Chwu Kperie 08	106.2	110.00	106.00
P2	Were Zawan	69.50	69.00	70.00
P3	Aburu Bwoi 07	98.20	99.70	100.00
P4	Nding Zawan	69.10	68.60	70.00

P5	Gyetel Burum 06	69.90	70.33	68.60
P6	Chwe Rihwe Ansie 08	70.10	71.00	70.40
P7	Chisu Mangu 08	77.20	76.60	78.00
P8	Lub Bungha 07	73.40	73.80	74.60
P11	Aburu Bakkanik 06	100.1	102.20	106.70
P12	Udin Gyetel 06	70.20	71.20	69.70
P13	Takwal Fier 06	69.23	69.00	68.60
P15	Chwe Rikwi Kpa Guriea 08	69.30	68.60	70.20
P16	Mayama Du 03	71.50	71.20	70.80
P17	Udin Bakkanik 06	68.40	68.50	69.33
P19	Mbulus Nga 07	69.30	70.20	69.60
P21	Peng Madu 03	109.70	109.20	110.20
P22	Sala Gyel 01	73.60	74.00	73.60
P23	Bwut Madu 03	99.50	98.90	100.20
P24	Chwu Zashi 08	105.70	106.20	105.80
P25	Jan Buru Chiga 06	104.90	104.60	105.20
P26	Chikarai Jwakras 08	71.20	71.40	73.80
P27	Gindiri Vwang 06	69.70	69.40	70.20
K1	Ziyan 08	71.20	70.30	71.80
K2	Wuwam 08	71.40	70.60	71.80
K3	Zealt 06	70.60	71.20	69.90
K4	Halat Jaba 08	99.50	100.8	100.40
B1	Wyandat 08	68.90	69.20	69.60
B3	Wyant 06	69.70	69.60	70.40
B4	Hlad 06	70.20	70.20	71.20
B5	Chid Kusung 06	69.80	70.00	70.20
LSD		0.3269	1.204	1.847
CV (%)		0.25	1.41	1.41

Table 2: Mean Stem Girth (cm) of 30 accessions in 2012, 2013 and 2014

		Stem Girth (cm)		
Accession Code	**Accession Name**	**2012**	**2013**	**2014**
P1	Chwu Kperie 08	2.4000	2.4100	2.3870
P2	Were Zawan	0.9000	0.9067	0.9333
P3	Aburu Bwoi 07	2.3000	2.3100	2.3200
P4	Nding Zawan	0.8000	0.8100	0.8000
P5	Gyetel Burum 06	0.9000	0.9067	0.9000
P6	Chwe Rihwe Ansie 08	1.1000	1.2000	1.0000
P7	Chisu Mangu 08	1.2000	1.2000	1.1000
P8	Lub Bungha 07	1.1000	1.1000	1.2000
P11	Aburu Bakkanik 06	2.3000	2.3030	2.3000
P12	Udin Gyetel 06	0.9000	0.9000	1.0000
P13	Takwal Fier 06	0.8000	0.8000	0.9000
P15	Chwe Rikwi Kpa Guriea 08	0.9000	0.9000	0.8000
P16	Mayama Du 03	0.6333	1.0670	0.9333
P17	Udin Bakkanik 06	0.8000	0.9000	0.8000
P19	Mbulus Nga 07	0.9000	0.9000	0.8000
P21	Peng Madu 03	2.4670	2.5000	2.4000
P22	Sala Gyel 01	1.2000	1.1000	1.0000
P23	Bwut Madu 03	2.5000	2.4000	2.4000
P24	Chwu Zashi 08	1.2000	2.5000	2.4000
P25	Jan Buru Chiga 06	2.5000	2.4000	2.5000
P26	Chikarai Jwakras 08	1.3000	1.2000	1.1000
P27	Gindiri Vwang 06	0.8000	0.9000	0.8000

K1	Ziyan 08	0.9000	0.9000	0.8000
K2	Wuwam 08	1.0670	1.0000	1.0000
K3	Zealt 06	1.2000	1.1000	1.0000
K4	Halat Jaba 08	2.2000	2.3000	2.4000
B1	Wyandat 08	0.9000	0.8000	0.9000
B3	Wyant 06	0.8000	0.8000	0.8000
B4	Hlad 06	0.9000	1.0000	1.0000
B5	Chid Kusung 06	0.8000	0.9000	0.8667
LSD		0.2311	0.1934	0.1863
CV (%)		10.98	8.7	8.7

Table 3: Mean Leaf Length of 30 accessions in 2012, 2013 and 2014

		Leaf Length (cm)		
Accession code	**Accession Name**	**2012**	**2013**	**2014**
P1	Chwu Kperie 08	16.00	20.40	20.80
P2	Were Zawan	17.02	16.90	16.60
P3	Aburu Bwoi 07	21.60	22.10	23.10
P4	Nding Zawan	12.10	13.60	13.90
P5	Gyetel Burum 06	14.60	14.80	14.90
P6	Chwe Rihwe Ansie 08	14.60	14.70	15.00
P7	Chisu Mangu 08	15.40	15.60	15.80
P8	Lub Bungha 07	16.60	16.90	16.80
P11	Aburu Bakkanik 06	22.70	23.20	23.10
P12	Udin Gyetel 06	15.07	15.50	15.60
P13	Takwal Fier 06	13.70	13.80	13.90
P15	Chwe Rikwi Kpa Guriea 08	14.60	14.60	14.80
P16	Mayama Du 03	16.30	16.40	16.60
P17	Udin Bakkanik 06	14.60	14.80	14.60
P19	Mbulus Nga 07	13.60	14.00	13.90
P21	Peng Madu 03	23.60	23.40	23.60
P22	Sala Gyel 01	13.90	14.00	14.10
P23	Bwut Madu 03	20.60	21.60	21.10
P24	Chwu Zashi 08	21.30	21.60	21.40
P25	Jan Buru Chiga 06	25.40	24.80	25.10
P26	Chikarai Jwakras 08	13.90	14.60	14.60
P27	Gindiri Vwang 06	16.30	16.67	16.90
K1	Ziyan 08	13.40	13.60	13.80
K2	Wuwam 08	14.60	14.80	14.80
K3	Zealt 06	13.70	14.00	14.10
K4	Halat Jaba 08	23.60	23.40	23.60
B1	Wyandat 08	14.80	14.60	14.80
B3	Wyant 06	14.50	14.60	14.80
B4	Hlad 06	13.60	13.90	14.00
B5	Chid Kusung 06	14.40	14.50	14.80
LSD		0.2532	0.2479	0.2193
CV (%)		0.94	0.79	0.79

Table 4: Mean Leaf Width of 30 accessions in 2012, 2013 and 2014

		Leaf Width (cm)		
Accession code	**Accession Name**	**2012**	**2013**	**2014**
P1	Chwu Kperie 08	1.0330	1.1000	1.1000
P2	Were Zawan	0.9000	0.8000	0.9000
P3	Aburu Bwoi 07	1.0000	1.0000	1.0000
P4	Nding Zawan	0.8000	0.9000	0.9333
P5	Gyetel Burum 06	0.9000	0.8000	0.9333

P6	Chwe Rihwe Ansie 08	0.7000	0.7200	0.8000
P7	Chisu Mangu 08	0.9000	0.9400	0.9000
P8	Lub Bungha 07	0.9000	0.9300	0.9000
P11	Aburu Bakkanik 06	1.0000	1.0000	1.1000
P12	Udin Gyetel 06	0.6500	0.7000	0.8000
P13	Takwal Fier 06	0.7000	0.7000	0.8000
P15	Chwe Rikwi Kpa Guriea 08	0.7000	0.7000	0.7000
P16	Mayama Du 03	0.7000	0.8000	0.8000
P17	Udin Bakkanik 06	0.7000	0.8000	0.8000
P19	Mbulus Nga 07	0.6000	0.7000	0.7000
P21	Peng Madu 03	1.0000	1.1000	1.0000
P22	Sala Gyel 01	0.6000	0.7000	0.7000
P23	Bwut Madu 03	1.3000	1.2000	1.1670
P24	Chwu Zashi 08	1.1000	1.2000	1.1000
P25	Jan Buru Chiga 06	1.1000	1.1000	1.0000
P26	Chikarai Jwakras 08	0.8000	0.8500	0.8000
P27	Gindiri Vwang 06	0.7000	0.7000	0.8000
K1	Ziyan 08	0.8000	0.8000	0.9000
K2	Wuwam 08	0.9000	0.8000	0.9000
K3	Zealt 06	0.9000	0.8667	0.8000
K4	Halat Jaba 08	1.1000	1.2000	1.2000
B1	Wyandat 08	0.7000	0.8000	0.7000
B3	Wyant 06	0.7000	0.7000	0.8000
B4	Hlad 06	0.8000	0.8000	0.7000
B5	Chid Kusung 06	0.7000	0.7000	0.8000
LSD		0.1634	0.1367	0.1551
CV (%)		11.57	10.89	10.89

Table 5: Mean Number of Days to Maturity of 30 accessions in 2012, 2013 and 2014

		Number of Days to Maturity		
Accession code	**Accession Name**	**2012**	**2013**	**2014**
P1	Chwu Kperie 08	153.0	154.0	155.0
P2	Were Zawan	132.0	133.0	133.0
P3	Aburu Bwoi 07	152.0	154.0	155.0
P4	Nding Zawan	130.0	130.0	131.7
P5	Gyetel Burum 06	132.0	133.0	133.0
P6	Chwe Rihwe Ansie 08	134.0	134.0	134.7
P7	Chisu Mangu 08	135.0	135.0	135.0
P8	Lub Bungha 07	138.0	140.0	138.0
P11	Aburu Bakkanik 06	152.0	152.0	154.0
P12	Udin Gyetel 06	136.0	136.0	136.0
P13	Takwal Fier 06	134.0	133.0	136.0
P15	Chwe Rikwi Kpa Guriea 08	132.0	133.0	133.0
P16	Mayama Du 03	145.0	143.0	144.0
P17	Udin Bakkanik 06	133.0	133.0	132.0
P19	Mbulus Nga 07	135.0	135.0	135.0
P21	Peng Madu 03	156.0	157.0	158.0
P22	Sala Gyel 01	132.0	134.0	133.0
P23	Bwut Madu 03	157.0	160.0	159.0
P24	Chwu Zashi 08	154.3	156.0	156.0

P25	Jan Buru Chiga 06	152.0	154.0	156.0
P26	Chikarai Jwakras 08	141.0	140.0	141.0
P27	Gindiri Vwang 06	131.0	132.0	133.0
K1	Ziyan 08	132.0	131.0	132.0
K2	Wuwam 08	132.0	133.0	133.0
K3	Zealt 06	132.0	134.0	134.0
K4	Halat Jaba 08	157.0	158.0	158.0
B1	Wyandat 08	132.0	133.0	133.0
B3	Wyant 06	132.0	132.0	133.0
B4	Hlad 06	132.0	134.0	132.0
B5	Chid Kusung 06	132.0	133.0	133.0
LSD		1.893	2.663	2.028
CV (%)		0.83	0.88	0.88

Table 6: Mean 1000 Seed Weight of 30 accessions in 2012, 2013 and 2014

		1000 Seed Weight (g)		
Accession code	**Accession Name**	**2012**	**2013**	**2014**
P1	Chwu Kperie 08	0.7122	0.7321	0.7123
P2	Were Zawan	0.5231	0.5243	0.5241
P3	Aburu Bwoi 07	0.7125	0.7201	0.7112
P4	Nding Zawan	0.5117	0.5132	0.5123
P5	Gyetel Burum 06	0.5213	0.5234	0.5203
P6	Chwe Rihwe Ansie 08	0.5321	0.5354	0.5342
P7	Chisu Mangu 08	0.5143	0.5232	0.5124
P8	Lub Bungha 07	0.5134	0.5223	0.5136
P11	Aburu Bakkanik 06	0.7213	0.7246	0.7216
P12	Udin Gyetel 06	0.5612	0.5634	0.5612
P13	Takwal Fier 06	0.5432	0.5432	0.5431
P15	Chwe Rikwi Kpa Guriea 08	0.5112	0.5134	0.5212
P16	Mayama Du 03	0.5532	0.5548	0.5578
P17	Udin Bakkanik 06	0.5462	0.5432	0.5432
P19	Mbulus Nga 07	0.5114	0.5124	0.5124
P21	Peng Madu 03	0.7126	0.7124	0.7234
P22	Sala Gyel 01	0.5786	0.5764	0.5764
P23	Bwut Madu 03	0.7543	0.7564	0.7567
P24	Chwu Zashi 08	0.7234	0.7224	0.7254
P25	Jan Buru Chiga 06	0.7163	0.7175	0.7123
P26	Chikarai Jwakras 08	0.6213	0.6123	0.6201
P27	Gindiri Vwang 06	0.5563	0.5557	0.5576
K1	Ziyan 08	0.5770	0.5768	0.5743
K2	Wuwam 08	0.6243	0.6324	0.6398
K3	Zealt 06	0.6054	0.6104	0.6046
K4	Halat Jaba 08	0.7254	0.7243	0.7221
B1	Wyandat 08	0.5762	0.5676	0.5676
B3	Wyant 06	0.5143	0.5201	0.5231
B4	Hlad 06	0.5543	0.5564	0.5565
B5	Chid Kusung 06	0.6123	0.6124	0.6056
CV (%)		1.24	0.04	0.04

Correlation analysis revealed a positive and highly significant correlation between plant height (PH) and stem girth (SG) implying that the taller the plant, the wider the stem girth (Table 7). This trend was observed between plant height and leaf length (LL), leaf width (LW), number of days to maturity (DM) and a thousand-seed weight, with the corresponding values of 0.875, 0.808, 0.940 and 0.899 respectively.

This trend was also observed between stem girth (SG) and leaf length (LL), leaf width (LW), number of days to maturity and a thousand-seed weight, with the corresponding values of 0.823, 0.780, 0.894 and 0.870. Again, this observation was exhibited between leaf length (LL) and leaf width, number of days to maturity (DM) and a thousand seed weight; and, between leaf width (LW) and number of days to maturity (DM), and a thousand seed weight (1000S). There was also, a highly significant and positive correlation between number of days to maturity and a thousand seed weight.

Table 7: Mean Correlation Coefficients Between Pairs of Morphological Traits 2012 to 2014 PH(cm), SG(cm), LL(cm), LW(cm), DM, 1000S(g)

	PH(cm)	SG(cm)	LL(cm)	LW(cm)	DM
SG (cm)	0.913				
	0.000				
LL (cm)	0.875	0.823			
	0.000	0.000			
LW (cm)	0.808	0.780	0.749		
	0.000	0.000	0.000		
DM	0.940	0.894	0.867	0.781	
	0.000	0.000	0.000	0.000	
1000S (g)	0.899	0.870	0.793	0.778	0.883
	0.000	0.000	0.000	0.000	0.000

Cell Contents: Pearson correlation P-Value

Key:

PH (cm) = Plant Height (cm)

SG (cm) = Stem Girth (cm)

LL (cm) = Leaf Length (cm)

LW (cm) = Leaf width (cm)

DM = Number of days to maturity

1000S (g) = 1000 Seed Weight (g)

The results of the Principal Component Analysis (PCA) showed that 95.4% of the total variation was contributed by the first three principal component axes. It was found that Principal Component I (PC1) contributed 87.1% whereas PC2 and PC3 contributed 4.7 and 3.6% respectively of the total variation. The traits which contributed more to PC1 were plant height (PH), stem girth (SG), number of days to maturity (DM) and 1000 seed weight (1000S). PC2 was dominated by leaf width (LW) while the PC3 was dominated by leaf length (LL) and 1000 seed weight. The first three principal components (PCs) explained 95.4% of the total variation in the six variables data set. The PC1, PC2 and PC3 showed relatively large variation with eigenvalues 5.2234, 0.2833 and 0.2155 respectively. The eigenvalues of PC1 greater than one and represented exact linear dependency but the rest had small variance (eigenvalues less than 1) as seen in Table 8.

Table 8: Mean Eigen analysis of the Correlation Matrix of Morphological traits for the three cropping seasons

Eigenvalue	5.2234	0.2833	0.2155	0.1262	0.0958	0.0558
Proportion	0.871	0.047	0.036	0.021	0.016	0.009
Cumulative	0.871	0.918	0.954	0.975	0.991	1.000
Variables	PC1	PC2	PC3	PC4	PC5	PC6
PH (cm)	-0.425	-0.146	-0.048	-0.043	0.307	-0.836
SG (cm)	-0.413	-0.145	-0.266	-0.742	-0.409	0.138
LL (cm)	-0.399	-0.246	0.790	0.188	-0.341	0.066
LW (cm)	-0.381	0.915	0.112	-0.021	0.042	0.044

DM	-0.420	-0.230	-0.018	-0.010	0.710	0.516
1000S (g)	-0.409	-0.079	-0.539	0.641	-0.341	0.094

Key:

PH (cm) = Plant Height (cm)
SG (cm) = Stem Girth (cm)
LL (cm) = Leaf Length (cm)
LW (cm) = Leaf width (cm)
DM = Number of days to maturity
1000S (g) = 1000 Seed Weight (g)
PC = Principal Component

The dendrogram (Figure 1) showed that the 30 accessions that were clustered together indicated that they shared similar traits. All the accessions are separated along the 100% baseline. On the one hand, accessions 3 and 18 both formed separate clusters implying that they are distinct from each other, while 5, 28, and 30 were grouped together, showing that they have similar grain and traits. At about 90% similarity, the accessions 1, 3, 9, 18, 26,16, 19 and 20 form one group, and 2, 22, 5, 28, 30, 12, 27, 29, 23, 25, 14, 24, 11, 15, 6, 10, 17, 4, 8, 21, 13 and 7 from a second group. The dendrogram suggests that accession 1, 3, 9, 18, 26, 16, 19, and 20 are similar measures for one main component and 2, 22, 5, 28, 30, 12, 27, 29, 23, 25, 14, 24, 11, 15, 6, 10, 17, 4, 8, 21, 13 and 7 are similar measure for a second main component. Cluster group two has higher similarity degree than cluster group one. Sub cluster groups also exist, that is, 2 and 22, 5 and 28, 12 and 27. On the other hand, 28 and 30 clusters have higher similarity percentage than all cluster groups (almost 100%). Clusters 3 and 9 have higher similarity (90 – 95%) in the first group. All accessions also, form one cluster group at about 44.06% similarity.

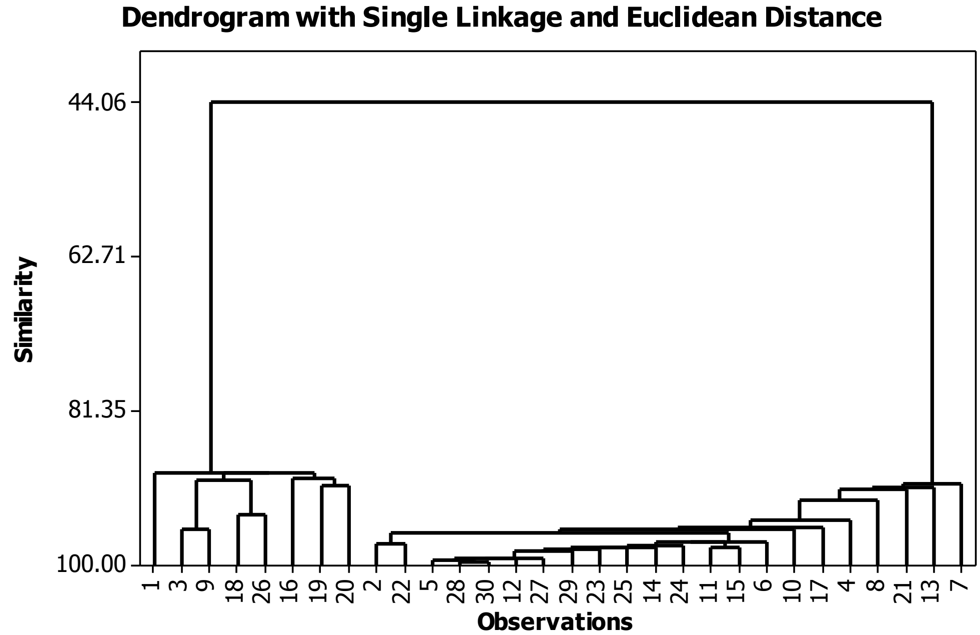

Figure 1: Dendrogram of Morphological Characters Showing the Linkage among Thirty Accessions of Acha for three cropping seasons

The output of clustering the 30 accessions to PH Plant Height (cm), SG Stem Girth (cm), LL Leaf Length (cm), LW Leaf width (cm), Number of days to maturity and 1000 Seed Weight (g) is given in Table 15 below. The first step, number 29 joins accessions 28 and 30 into a cluster called CL29 with distance level 0.1721 at similarity of 99.6531. The next step, number 28, joins accession 5 and 28 into CL28 with distance level 0.3163 at similarity 99.3622. The procedure continues until all accessions have been grouped together into the last cluster CL1, which is a combination of accession1 and accession 2 with distance level 27.7435 at similarity 44.0590. The similarity measure decreases little during the first 19 steps, where 11 clusters remain. Then it decreases somewhat more until step 28, where we are left with 2 clusters. At step 29, a larger drop occurs with 1 cluster joining accession 1 and 2.

Table 9: Cluster Analysis of Observations of Morphological Characters

Euclidean Distance, Single Linkage Amalgamation Steps

Step	No. of clusters	Similarity level	Distance level	Clusters joined		New cluster	No. of obs. in new cluster
1	29	99.6531	0.1721	28	30	28	2
2	28	99.3622	0.3163	5	28	5	3
3	27	99.1445	0.4243	5	12	5	4
4	26	99.0888	0.4519	5	27	5	5
5	25	98.1704	0.9074	5	29	5	6
6	24	97.9432	1.0201	5	23	5	7
7	23	97.7995	1.0913	11	15	11	2
8	22	97.7253	1.1281	5	25	5	8
9	21	97.7002	1.1406	5	14	5	9
10	20	97.5041	1.2378	5	24	5	10
11	19	97.4419	1.2687	2	22	2	2
12	18	97.1060	1.4353	5	11	5	12
13	17	97.0673	1.4544	5	6	5	13
14	16	96.0178	1.9749	2	5	2	15
15	15	95.6317	2.1664	2	10	2	16
16	14	95.5731	2.1955	3	9	3	2
17	13	95.3005	2.3307	2	17	2	17
18	12	94.4883	2.7335	2	4	2	18
19	11	93.9071	3.0217	18	26	18	2
20	10	91.9890	3.9730	2	8	2	19
21	9	90.7178	4.6034	2	21	2	20
22	8	90.5522	4.6856	2	13	2	21
23	7	90.3004	4.8104	19	20	19	2
24	6	90.0595	4.9299	2	7	2	22
25	5	89.6810	5.1176	3	18	3	4
26	4	89.5246	5.1952	16	19	16	3
27	3	88.8862	5.5118	3	16	3	7
28	2	88.8114	5.5489	1	3	1	8
29	1	44.0590	27.7435	1	2	1	30

Evaluation of the phenotypic and genotypic characters for the different accessions in this study shows that the genotype expressed more variability in genetic diversity for plant height, leaf length, and days to maturity and 1000 seed weight in the three-year field trials. The effect of genetic variability in plant improvement or breeding is well documented. Hammad *et al.*, [9] reported the considerable genetic variability that exists in wheat genotypes for yield improvement, stressing that both additive and non-additive gene actions were involved in the expression of yield components. Govindaraj *et al.*, [10] reported the importance of genetic diversity in conservation of crop plants.

Plant height has been reported to be an important yield trait [9] that directly affects plant yield. However, in this study, plant height was positively correlated to all yield attributes, suggesting that the taller accessions had a yield advantage over the shorter ones. It will imply from these results that lodging was inconsequential among the taller plants. In this study, the principal component analysis showed that plant height contributed very highly to the total variation with respect to yield. In the three years of analyses, plant height appeared among the first three principal components, indicating that plant height was crucial in the determination of yield in the Acha.

Even though short stature plants have been reported in other cereals such as wheat to be preferred in varietal development since they are resistant to lodging and more responsive to fertilizers as observed by Hammad *et al*., [9], this does not seem to be so with Acha as the accessions with the tallest plants gave the best grain yields. It is likely that lodging is not a problem among the Acha accessions evaluated

The accessions with the widest stem girth appeared to have the heaviest 1000 Seed weight, implying the highest grain yield. In some literatures, it has been suggested that this character should assist in lodging resistance. Short stiff culm has been considered the most important morphological character that has contributed to breeding high yielding rice and wheat varieties by giving lodging resistance. Lodging has been described as the process by which the shoots of small grained cereals are permanently displaced from their vertical stance. He further explained that lodging limits yield potential and reduces grower profits, but that it is difficult to control because it is a complex process that is influenced by many factors including wind, rain, topography, soil type, previous crop, crop management, and disease.

Variability existed among the accessions with respect to 1000 seed weight in all the the years, indicating suitability for sorting out genotypes with superior grain weight. Hammad *et al*., [9] reported that a significant variability in seed index/grain weight is essential for the breeder to sort out genotypes with superior grain weight that result in higher grain yield.

Conclusion

In this study, plant height was positively correlated to all yield attributes, suggesting that the taller accessions had a yield advantage over the shorter ones, implying that lodging was inconsequential among the taller plants. The accessions (1, 3, 9, 18, 26, 16, 19 and 20) with the widest stem girth, appeared to have the heaviest 1000 seed weight, implying the highest grain yield. Accessions with longest leaf lengths had the heaviest 1000 seed weights, indicating better grain yield. Variation also existed among the accessions with respect to leaf width. The extreme usefulness of wider leaf width for selection of high yielding varieties [11]. Leaf width correlated positively with 1000 seed weight in all the years thereby agreeing with the results of their findings. This also agrees with the work of Sahin and Metin [12], where flag leaf width was positively correlated with grain yield per plant and suggested that successful selection could be practiced for this trait. They observed also, that the flag leaf width and grain yield per plant traits were significant.

Accessions with late maturing ability appeared to have done better than the early maturing types. The low yields of the early maturing types may be related to the humid weather conditions prevalent in the study area at the time of maturity.

Variability existed among the accessions with respect to 1000 seed weight in all the years, indicating suitability for sorting out genotypes with superior grain weight/yield.

Evaluation of the phenotypic and genotypic characters for the different accessions in this study shows that the genotype had more variability in genetic diversity for plant height, leaf length, days to maturity and 1000 seed weight in the three-year field trials.

RFLPs appear to suggest a clear separation of the 3 species (*D. iburua, D. exilis* and *D. barbinodis)* demonstrating their genetic differences at the molecular/DNA level.

Further studies of this nature should incorporate samples from the diverse Acha producing areas of Nigeria. Also, the promising accessions in terms of yield and yield components should be incorporated in multilocational and advanced yield trials with the aim of having uniform yielding accessions that can be further employed in future breeding and selection work for this crop.

The collection of accessions for this study was limited to only some Acha growing areas of Bauchi, Plateau and Kaduna states. Other production hotspots in the study areas which are engaged in Acha production were not visited for germplasm collection.

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