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GENETIC POTENTIALS OF PEARL MILLET (*PENNISETUM GLAUCUM* (L.) R. BR.) FOR ENHACED GRAIN YIELD AND BIOGASS PRODUCTION IN SEMI ARID REGIONS OF NIGERIA

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Abstract
Field experiments were conducted at two locations (Sokoto and Kebbi states) to determine the genetic potentials of 100 Pearl millet (Pennisetum glaucum) genotypes comprising 10 parents and 90 hybrids generated using a complete diallel mating design for both Food and Biogas production in semi-arid environments. Mean performance and Heritability Estimates were determined for growth, yield, and proximate characters. The results of the experiments showed significant ($P<0.05$) variation in the characters considered. High grain and Stover yields (2.5-3.2t/ha and 15.8-22.5t/ha respectively) were observed among the genotypes. All the characters measured showed high level of heritability in broad sense (98.61% to 13.04). It was concluded that Pearl Millet has an excellent potential use as dual purpose crop (for both grain and biogas) in the study area. The hybrid UDUS2020×005 was selected as the genotype with the best grain yield, biomass yield, and lower C:N ratio (3.2t/ha, 22.5t/ha and 2.71) respectively.

INTRODUCTION

Pearl millet (*Pennisetum glaucum* (L.) R. Br.) Is a member of the grass family Poacea. It is the most important species and probably has the greatest potential. It is a robust, quick-growing cereal. It is one of the most important dual-purpose crops and a staple food for millions of people in arid and semi-arid ecologies around the world (Chopra, 2001). Pearl millet is the sixth most important cereal annually cultivated as a rain-fed crop in arid and semi-arid areas of Africa and the Indian subcontinent (Khairawal *et al.*, 1999; FAO, 2007).

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India is the largest producer of pearl, producing 10,280,000 tonnes with an average productivity of 1,163kg/ha, followed by Niger producing 3,886,079 tonnes with an average productivity of 538kg/ha, China with 1,996,378 tonnes and an average productivity of 2,675 kg/ha, Mali produces 1,806,559 tonnes with an average productivity of 886kg/ha and Nigeria produces 1,468,668 tonnes with an average productivity of 846kg/ha (FAO, 2017). The world's pearl millet production is 28,357,451 tonnes, with an average productivity of 894kg/ha (FAO, 2017).

The stalks are used to make mulch and as fuel for cooking. People with celiac diseases can replace certain gluten-containing cereals in their diets with pearl millet (Chopra, 2001). Pearl millet has significant potential as a food grain, feed, and fuel (Savage, 1995).

Biogas production depends on various factors. Prominent among these factors are the pH, the concentration of the slurry, temperature, and, more importantly, the C/N ratio, which controls the pH value of the slurry. Total solids, volatile matter, and mineral concentrations are among the factors affecting biogas yields. The production of biogas will enhance the clean environment through the killing of pathogens during anaerobic digestion, thus producing fertilizer very rich in NPK. Biogas has applications in cooking, lighting, and electricity generation, among other uses (Dioha *et al.*, 2013).

According to Falconer and Mackay (1996), heritability is defined as a measure of the correspondence between breeding and phenotypic values. Thus, heritability plays a predictive role in breeding, expressing the reliability of a phenotype as a guide to its breeding value. The breeding value which determines how much of the phenotype is passed to the next generation (Tazeen *et al.*, 2009). The objective of this research is to determine the broad sense heritability of pearl millet character with the aim of selecting a dual-purpose millet that can be used for food and biogas production.

MATERIALS AND METHODS

Two separate field experiments were conducted at Sokoto (Dry Land Teaching and Research Farm, Usmanu Danfodiyo University, Sokoto) and Kebbi (Bui, Arewa L G A). Sokoto is located at latitude 13^{o} 8'N and longitude 5^{o} 13'E and at an altitude of 278m above the sea level. While Kebbi (Bui Arewa LGA) is located at latitude 12^{0} 7'N and longitude 4^{0} 15'E and at an altitude of 244.92m above sea level.

Sokoto falls under the Sudan Savannah ecological zone, which is characterized by a long dry season and a short rainy season. The mean annual rainfall varies from 345 mm to 751 mm northwards (S.E.R.C, 2016). Rainfall mainly starts in May and ends in September, with a peak in August. The maximum and minimum temperatures of the area range from 40^{o}C and 15^{o}C, respectively (Arnborg, 1988). The Kebbi (Bui, Arewa LGA) has mean annual rainfall ranging from 217 mm to 807 mm. Rainfall mainly starts in April and ends in October, with a peak in August. The maximum and minimum temperatures of the area range from 40.3°C and 16.6°C, respectively (Ismail and Oke, 2012).

The soil of the experimental area was sampled from 0-15 cm and 15-30 cm from five locations within the area and bulked. Composite samples collected from the bulk were analyzed for physical and chemical properties.

The treatments consisted of 100 genotypes of pearl millet (10 parents 90 hybrids). The treatments were sown in Alpha Design (AD) with two replications. Each block contained 10 plots.

Data were recorded on number of hills after emergence (NHE), days to 50% flowering (D50%FL), plant height (PHT), panicle length (PNLE), number of hills at harvest (NHH), number of plants at harvest (NPLH), panicle circumference (CIR), compactness of panicle (CMP), Biomass Yield (BMS), panicle weight per plot (PWP), grain weight per plot (GWP), and Carbon to Nitrogen Ratio (CNR).

Analysis of variance was performed using Genstat (17th edition) for each individual season and for combined seasons. Estimates of phenotypic ($\sigma 2ph$) and genotypic ($\sigma 2g$) variances were calculated using mean square values obtained from individual and combined ANOVA.

a. The individual analysis of variance was estimated as follows:

$\sigma^2 g = (M2 - M1)/r$ $\sigma^2 ph = \sigma^2 g + \sigma^2 e$

Where: r = number of replications.

$\sigma^2 e$ = error or environmental variance. `

M1, M2 = error and genotype mean squares.

b. The combined analysis of variance was estimated as follows:
Genotypic variance ($\sigma^2 g$) = (M2-M1)/rL
Phenotypic variance ($\sigma^2 ph$) = $\sigma^2 g + \sigma^2 gS + \sigma^2 e$
Where: g = number of genotypes.
Here, L and r = number of Locations and replications, respectively.
$\sigma^2 e$ = error or environmental variance.
M1= expected mean squares of pooled error M2= expected mean squares of genotypes x seasons interaction.
The phenotypic (PCV) and genotypic (GCV) coefficients of variation (individually and combined) were calculated using the following formula:
Phenotypic coefficient of variation (PCV) = ($\sqrt{\sigma^2 Ph}$/ Grand mean) × 100
Genotypic coefficient of variation (GCV) = ($\sqrt{\sigma^2 g}$/ Grand mean) x 100
Heritability percentage in broad sense h2 (bs) and Genetic advance (GA) were estimated according to the method suggested by Johnson *et al.* (1955) as the following formulas:
h^2 (bs) from individual analysis of variance:
$h^2(bs) = \sigma^2 g / \sigma^2 ph$
Where: $\sigma^2 g$, $\sigma^2 ph$ = genotypic and phenotypic variances, respectively.
h^2 (bs) from the combined analysis of variance: It was calculated as the ratio of the genotypic variance to the phenotypic variance according to the following formula:
h^2 (bs) = $\sigma^2 g / [\sigma^2 g + \sigma^2 gs + \sigma^2 e]$ rL
Where:
$\sigma^2 g$ = is the estimated genetic variance
$\sigma^2 gL$ = the variance due to genotypes x Location interaction.
$\sigma^2 e$ = is the pooled error variance
Here, L and r = represent the number of Locations and replications, respectively.

RESULTS AND DISCUSSION

Soil Analysis

The results obtained from the soil analysis at the two experimental sites indicate that the particle size distributions at the two sites were sandy. The pH values indicate that the soils of the two experimental sites were slightly acidic. The soils had low organic carbon, total nitrogen, sodium, and cation exchange capacity, while the available potassium and magnesium were moderate (Table 1).

Table 1: Physical and chemical properties of soil of the experimental sites at Sokoto (Usmanu Danfodiyo University, Teaching and research Dry Land Farm Sokoto) and Kebbi (Bui Arewa LGA) during the 2020 rainy season.

Physical and chemical properties/Samples	**Sokoto**	**Kebbi**
Particle size distribution	0-15 (cm)	16-30 (cm)
P^H	5.50	5.70
Org. C (%)	0.12	0.08
Org. M (%)	0.21	0.14
N (%)	0.03	0.03
P (mg/kg)	0.47	0.46
Ca (Cmol/kg)	0.55	0.50
Mg (Cmol/kg)	0.20	0.10
K (Cmol/kg)	0.90	0.77
Na (Cmol/kg)	0.52	0.30
CEC (Cmol/kg)	3.84	3.54
Sand (%)	88.80	88.80
Silt (%)	9.20	9.20
Clay (%)	2.00	2.00

The highest phenotypic and genotypic variances were observed in grain weight (kg/ha) (41942.60 and 35345.40 respectively) at Sokoto, while the lowest phenotypic and genotypic variances were observed in stalk weight (0.05 and 0.04 respectively) followed by panicle compactness (0.35 and 0.17 respectively) (Table 3). At Bui, the highest phenotypic and genotypic variances were observed in panicle weight (672420.30 and 564283.70 respectively) followed by grain weight (kg/ha) (254432.65 and 215741.35 respectively). However, the lowest phenotypic and genotypic variances at Bui were observed in panicle compactness (0.99 and 0.20 respectively) followed by stalk weight 4.02 and 2.61 respectively) (Table 4).

The highest phenotypic and genotypic coefficients of variation were observed in downy mildew severity in the two Seasons and combined; Sokoto (127.46% and 116.54% respectively) (Table 3), Bui (195.45% and 175.93% respectively) (Table 4), and combined (134.46% and 120.35% respectively) (Table 5). The severity of downy mildew was followed by grain yield at Sokoto (88.77% and 175.93% respectively) (Table 3), the incidence of downy mildew at Bui (162.97% and 150.36% respectively) (Table 4) and also combined (133.66% and 120.35% respectively) (Table 5). The lowest values for phenotypic and genotypic coefficients of variation were observed at Sokoto (18.28% and 16.16% respectively) (Table 3) and combined (22.79% and 21.14% respectively) (Table 5). At Bui, however, panicle length had the lowest phenotypic (42.30%) and genotypic (21.14%) values (Table 4).

Table 2: Summary statistics of the data

	CIR	D50%FL	DMI %	DMS %	GWP Kg/ha	NHE	NHH	NPLH	PHT	PWP	STLWT (kg/plot)	CNR
Mean	6.144	64.03	20	3.651	445.8	5.002	4.569	7.416	120.9	578.7	1.419	12.21
Median	6.7	69	37.49	0	266.4	5	5	5	122	0.25	0.51	5.68
Minimum	1.3	45	2	2	50	4	4	5	75.6	251	0.98	2.71
Maximum	87	99	100	100	4900	19	10	38	122	7733	14.7	21.76
Standard deviation	3.983	26.42	0	9.915	550	2.927	2.873	7.616	76.21	965.1	2.029	8.42

CIR: panicle circumference, D50%FL: days to 50% flowering, DMI%: downy mildew incidence, DMS%: downy mildew severity, GWP kg/ha: grain weight (kg/ha), NHE: number of hills that established, NHH: number of harvested hills, PHT: Plant height, PWP: panicle weight, STLWT: stalk weight, and CNR: C:N ratio.

Table 3: Estimates of phenotypic and genotypic variances, phenotypic, genotypic, and environmental coefficients of variation estimates, and broad sense heritability for Growth and Yield Characters in millet evaluated at Usmanu Danfodiyo University, Sokoto Dry Land Farm during 2020 rainy season.

Traits	σph	σg	σe	PCV	GCV	ECV	H^2
NHE	4.07	3.42	0.65	37.61	34.48	3.13	84.05
D50% FL	130.77	102.23	28.54	18.28	16.16	2.11	78.18
PHT	3672.75	3039.25	633.50	54.94	49.98	4.96	82.75
DIM %	24.83	19.84	4.99	62.29	58.88	3.41	79.90
DMS %	24.33	20.34	3.99	127.46	116.54	10.91	83.60
NHH	4.98	2.759	2.22	43.321	32.23	11.08	55.36
NPLH	61.03	26.28	34.75	67.52	44.30	23.21	43.06
PNLE	228.40	203.9	24.50	33.94	32.07	1.87	89.27
CIR	3.24	0.58	2.66	28.45	12.06	16.39	17.97
CMP	0.35	0.17	0.18	22.99	16.01	6.98	48.50
PWP	9500.00	8200.00	0.00	62.53	57.83	4.69	85.55

STLWT	0.05	0.04	0.01	53.06	47.92	5.14	81.58
CNR	401.95	164.75	237.20	62.36	39.92	22.44	82.51
GWP kg/ha	41942.60	35345.40	6597.20	88.77	81.49	7.28	84.27

σph: phenotypic variance, σg: genotypic variance, σe: error variance PCV: phenotypic coefficient of variation, GCV: genotypic coefficient of variation, ECV: environmental coefficient of variation, H^2: broad sense heritability.

Table 4: Estimates of phenotypic and genotypic variances, phenotypic, genotypic, and environmental coefficients of variation estimates, and broad sense heritability for Growth and Yield Characters in millet evaluated at Kebbi (Bui, Arewa LGA) during the 2020 season.

Traits	σph	σg	σe	PCV	GCV	ECV	H^2
NHE	5.87	5.01	0.86	50.19	46.36	3.83	85.33
D50% FL (%)	859.35	440.55	418.80	44.73	32.03	12.70	51.27
PHT (cm)	3529.97	3324.04	205.93	44.31	42.99	1.31	94.17
DIM %	75.74	64.47	11.27	162.97	150.36	12.61	85.12
DMS %	47.80	39.54	8.27	193.45	175.93	17.53	82.70
NHH	5.56	5.49	0.07	56.53	56.16	0.37	98.69
NPLH	4.23	3.61	0.62	59.81	55.27	4.54	85.39
PNLE (%)	312.60	227.40	85.20	42.30	36.08	6.22	72.74
CIR (cm)	20.76	7.99	12.77	75.41	46.78	28.64	38.47
CMP	0.99	0.20	0.79	58.67	26.47	32.19	20.36
PWP (kg/ha)	672420.30	564283.70	108136.60	70.69	64.76	5.93	83.92
STLWT (kg/ha)	4.02	2.61	1.41	81.13	65.33	15.80	64.84
CNR	418.81	292.69	126.12	44.52	37.22	7.30	92.75
GWP kg/ha	254432.65	215741.35	38691.30	76.53	70.47	6.06	84.79

σph: phenotypic variance, σg: genotypic variance, σe: error variance PCV: phenotypic coefficient of variation, GCV: genotypic coefficient of variation, ECV: environmental coefficient of variation, H^2: broad sense heritability.

Table 5: Estimates of phenotypic and genotypic variances, phenotypic, genotypic, and environmental coefficients of variation estimates, and broad sense heritability for Growth and Yield Characters in millet evaluated at Usmanu Danfodiyo University, Sokoto Dry Land Farm during the 2017 season.

Traits	σph	σg	σe	PCV	GCV	ECV	H2
NHE	2.64	2.27	0.37	32.48	30.12	2.36	85.98
D50% FL (%)	212.95	183.25	29.70	22.79	21.14	1.65	86.06
PHT (cm)	1932.68	1698.33	234.35	36.36	34.09	2.28	87.87
DIM percentage (%)	25.11	20.36	4.75	133.66	120.35	13.31	81.08
DMS percentage (%)	24.10	18.80	5.30	134.46	118.76	15.70	78.01
NHH	2.64	2.33	0.31	35.56	33.41	2.15	88.26
NPLH	13.75	11.98	1.77	50.00	46.67	3.33	87.13
PNLE (cm)	117.33	100.17	17.16	25.38	23.45	1.93	85.37
CIR (cm)	6.19	3.25	2.94	40.48	29.34	11.14	52.55
CMP	0.40	0.05	0.35	29.77	10.75	19.02	13.04
PWP (kg/plot)	174170.38	146565.63	27604.75	72.12	66.15	5.96	84.15

STLWT (kg/plot)	0.94	0.80	0.14	68.25	62.96	5.30	85.08
CNR	173.60	146.90	26.70	33.82	31.11	2.71	84.62
GWP (kg/ha)	71851.58	70686.43	1165.15	60.13	59.64	0.49	98.38

σph: phenotypic variance, σg: genotypic variance, σe: error variance PCV: phenotypic coefficient of variation, GCV: genotypic coefficient of variation, ECV: environmental coefficient of variation, H^2: broad sense heritability.

The values of the phenotypic coefficient of variation (PCV) were higher than those of the genotypic coefficient of variation (GCV) values for all the traits (i.e positive environmental coefficient of variation (ECV)), which indicates the environmental role in trait expression. Higher PCV values than GCV values were reported by Khosa and Dhatt (2013); Musa and Atif (2013). Deshmukh et al. (1986) suggested that PCV and GCV values greater than 20% are regarded as high, values between 10% and 20% as medium, and values less than 10% are considered to be low. Based on the study of Deshmukh et al. (1986), the number of hills that established, plant height, downy mildew severity, number of hills at harvest, number of plants harvested, panicle length, panicle weight, stalk weight, C:N ratio, and grain weight (kg/ha) had high PCV and GCV in the two locations combined. Days to 50% flowering and downy mildew incidence recorded medium PCV and GCV values in Sokoto, but high GCV values in Bui and combined. Panicle circumference and panicle compactness were recorded as high PCV and medium GCV at Sokoto. This resulted in a high ECV at that location, indicating a high environmental influence on character. Although the PCV and GCV values were high at Bui and combined, the ECV was also very high indicating none reliability of the selection of these characters. High PCV and GCV in combined results of days to 50% flowering in pearl millet were reported by Musa and Atif (2013) and Govindaraj et al. (2011).

Results of heritability in a broad sense revealed that Panicle length obtained the highest heritability of 89.27%, followed by panicle weight (85.55%) and C:N ratio (82.51%) at Sokoto (Table 3). At Bui, however, the number of hills at harvest recorded the highest broad sense heritability of 98.69%, followed by plant height of 94.17% and C:N ratio of 92.75% (Table 4). Grain weight (kg/ha) recorded the highest broad sense heritability (98.38% followed by number of hills harvested (88.26% (Table 5). The lowest values of broad sense heritability were recorded for panicle compactness at Bui (20.36%) (Table 4) and combined (13.04%) (Table 5). According to Singh (2001), a heritability of 80% or more is considered high, and the selection of characters with such heritability could be fairly easy. This is because there would be a close correspondence between genotype and phenotype due to the relatively small contribution of the environment to the phenotype. A heritability of 40% or less is considered low. Thus, selection may be considerably difficult or virtually impractical due to the environment's masking effect. Heritability estimates between 40% and 80% are considered moderate. On this basis, plant height, downy mildew incidence, panicle length, panicle weight, stalk weight, C:N ratio, and grain yield are highly heritable characteristics (>80%) in the two seasons and combined. This indicates that environmental conditions have less impact on these characters, and as such, they are easier to select. Days to 50% flowering, was moderate in the two seasons and highly heritable in the combined analysis, indicating that even though the environment has an influence on this character to some extent, it is possible for the character to be selected with careful observation. Downy mildew severity had high heritability in Sokoto and Bui but was moderate in the combined analysis, although it was close to 80%. Indicating the possibility of selecting these characters through careful observation. The number of hills harvested and the number of plants harvested had moderate heritability at Bui only, indicating that the character can be selected for despite environmental influence. The panicle diameter had low heritability at Sokoto and Bui but moderate heritability in the combined analysis, indicating the difficulty with which the character may be selected. Panicle compactness had low heritability in the two individual locations; therefore, it is difficult or impossible to select for this characteristic in the population. This result was similar, though with minor differences with the results obtained by Andualem et al. (2013), who obtained moderate heritability for most of the characters studied in this research.

CONCLUSION

On the basis of the results of this study, it could be concluded that high amount of variability is present in the 100 genotypes. High to moderate PCVs and GCVs were observed for stalk weight, C:N ratio, grain weight (kg/ha), and other characteristics in the combined analysis. High broad sense heritability was also observed in the combined analysis for all the characters, with the exception of panicle compactness, which recorded low heritability, and downy mildew severity, which recorded medium heritability. Therefore, the selection of genotypes with high stover weight, low C: N ratio, and high grain yield could be possible and effective when using appropriate breeding and Selection methods.

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