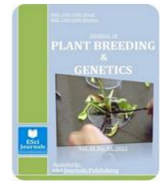
Available Online at ESci Journals

Journal of Plant Breeding and Genetics

ISSN: 2305-297X (Online), 2308-121X (Print)

http://www.escijournals.net/JPBG



EXPLORING VARIATION, RELATIONSHIPS AND HERITABILITY OF TRAITS AMONG SELECTED ACCESSIONS OF SORGHUM (*SORGHUM BICOLOR* L. MOENCH) IN THE UPPER EAST REGION OF GHANA

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A B S T R A C T

Sorghum is an important staple food crop in the northern regions of Ghana. The crop is used locally to prepare several meals such as 'tuo zaafi', porridge, cake and to brew a local beer known as 'pito'. Despite the important role of sorghum in nutrition and economy of Ghana, it attracts little research attention and recently low economic yield of sorghum is a great disincentive to farmers. Understanding of yield components of sorghum is needed to improve yield of existing local varieties. This study investigates the yield components of four local varieties of sorghum; *Banina*, *Kadaga*, *Naga red* and *Kapala*. The sudy was carried out at Navrongo in the Kassena-Nankana district of the Upper East region of Ghana. The varieties were evaluated for yield traits using Randomized Complete Block design with four replications. The results revealed that, significant variations were recorded among the yield traits studied. High values for phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) was recorded for harvest index and number of grains per panicle. High heritability accompanied with high genetic advance (GA) was observed for number of days to flowering, number of primary panicles, weight of grains per panicle, and days to maturity. *Banina* variety produced the highest number of leaves, panicle height, panicle width, plant height, number of grains per panicle, weight of grains per panicle, economic yield and biological yield. There was also significant and positive correlation between characters studied. Principal components analysis revealed that *Banina* was the highest yielding variety and number of grains per panicle was the principal contributing factor to the high yielding character of this variety. This indicates that local farmers could cultivate *Banina* to increase their yield and genetic improvement of number of grains per panicle by plant breeders could help to develop higher yielding varieties for enhancement of nutrition and livelihoods of the rural poor in the northern regions of Ghana.

Keywords: Sorghum, Yield, Yield components, Association, Heritability, Genetic advance.

INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench), a tropical plant of the family poaceae, is one of the important cereal crops in Ghana. Commonly defined as a multi-purpose crop, it is mainly grown in the northern regions of Ghana .The three Northern regions where sorghum is grown are also the poorest in Ghana as 40% of the population in these regions lives below the poverty line (Ghana Statistical Service, 2000). The resilience of sorghum – in terms of drought resistance and ability to withstand high temperatures – makes it crucial for food security in these regions (Kudadjie *et al.*, 2004). The milled grains are used to prepare food (*tuo zaafi, koko* and *masa*) as well as the local opaque beer known as *pito*. Sorghum brewing is an important cottage industry in northern Ghana. During social events and religious ceremonies, pito is widely consumed, thus serves as a source of income for rural women and their households. Weaning food and baby food industries also make use of sorghum (Chandel and Paroda, 2000). Nutritionally it is rich in micronutrients, vitamins and proteins which can be used to address potential deficiencies (Chinedu *et al.*, 2011). Moreover sorghum leaves can serve as fodder for farm animals while the stalks are used for fencing, staking, roofing, weaving baskets and mats and also for

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fuel (Angelucci, 2013; Awika and Rooney, 2004; Dicko *et al*., 2006; Mehmood *et al*., 2008).

In spite of the beneficial uses and potential of sorghum as a cash crop for industrial brewing, the crop has been neglected by policy makers and scientific research especially with respect to the need to develop more productive and pest resistant varieties (Kudadjie *et al*., 2004). As a result, many of the cultivated varieties are still landraces and their cultivation is a disincentive for farmers due to pest and disease pressures, poor yield, small grain size and pre-harvest sprouting of seeds (Angelucci, 2013; Buah *et al*., 2010; Akuriba *et al*., 2011). Of the cereal crops grown in Ghana, sorghum used to rank third in terms of production value, after maize and rice, with a share of 12% on total cereal production value. The importance of sorghum in terms of area harvested has been decreasing during the last decade and it is now the 5th (Angelucci, 2013). The decrease in the importance of sorghum in Ghana cropping systems is mainly due to the cultivation of indigenous landrace varieties with inherent low yield potential.

Today, the development of modern and well adapted varieties of sorghum that could meet the needs of farmers and consumers becomes more important. The knowledge of genetic variability, heritability and association among economic traits in existing local varieties is a pre-requisite for selection and development of a well adapted variety (Falconer and Mackay, 1996, Jalata *et al*., 2011). Yield is a complex character and is influenced by many of its contributing characters controlled by polygenes and environmental factors. To improve yield of existing landraces, an understanding of genetics of components of yield is a necessity. The efficiency with which genotypic variability can be exploited by selection depends upon heritability and genetic advance of individual traits (Bilgin *et al*., 2010).

The objectives of this study were therefore to determine the amount of genetic variability, heritability, genetic advance and strength of association of yield related traits among some selected sorghum landraces in the Upper East region of Ghana.

MATERIALS AND METHODS

The Experimental Site: The experiment was carried out in Navrongo in the Kassena –Nankana District of the Upper East Region of Ghana. Navrongo is located in the Guinea Savannah belt, and the ecology is typically Sahelian (hot and dry), with the vegetation consisting mostly of semi-arid grassland interspersed with short tree. (Meteorological Service Department, 2011). The mean annual rainfall is 1365 mm but the highest level is recorded in August. Similarly, the dry season is subdivided into the Harmattan (November to mid-February) and the dry hot (mid-February to April) seasons. Annual average temperatures recorded in the Upper East Region, specifically at Navrongo in the dry season is 15^{o} C(Dec. to Feb.) at minimum limits and highest at 45^{o} (March to April). The relative Humidity ranges between 30% and 80% in the dry and wet season's respectively (Meteorological Services Department, 2011).

Planting materials: The grains of four local varieties of sorghum; *Kadaga*, *Banina*, *Naga red*, and *Kapala* were obtained from the Ministry of Food and Agriculture (MoFA) head office in Bolgatanga. The details of the local varieties are given in Table 1.

Table 1. Grain colour and head type of the four local varieties of sorghum.

Variety	Grain colour	Head Type
Kadaga	Brown	Loose
Banina	White	Loose
Naga Red	Red	Compact
Kapala	Cream	Compact

Experimental Design: The four varieties of grain sorghum were evaluated in a Randomized Complete Block Design (RCBD) with four replications. The varieties were sown at a planting distance of 25cm between rows and a spacing of 15cm between plants was maintained with 20 stands per plot.

Data collected: Five randomly selected plants were taken from each variety and replication and observations were recorded on different characters. These include number of leaves, plant height (cm), Days to 50% flowering, Days to maturity, Panicle length (cm), Panicle width (cm), Number of primary branches/ panicle, Number of grains/ panicle, Hundred grain weight (g), Total dry matter, Harvest index (%).

Data analysis: The data collected for each quantitative trait were subjected to Analysis of Variance (ANOVA) using GenStat ® 11th version (GenStat, 2008). Treatment means were tested for significance (LSD) at 5%.

Estimation of Variance Components: The phenotypic, genotypic and environmental variances and coefficient of variation were calculated according to the formula

suggested by Singh and Chaudhury (1999) as follows:
Environmental variance (δ^2e) = MSE

$$\text{Genotypic variance } (\delta^2 g) = \frac{MSG - MSE}{r}$$

$$\text{Phenotypic variance } (\delta^2 p) = \delta^2 g + \delta^2 e$$

Where, MSG is mean square due to genotype, MSE is mean square of error (environmental variance) and r is the number of replications.

$$\text{Phenotypic coefficient of variation (PCV)} = \sqrt{\frac{\delta 2p}{X}} \times 100$$

$$\text{Genotypic coefficient of variation (GCV)} = \sqrt{\frac{\delta 2g}{X}} \times 100$$

Where

δ^2p = phenotypic variation

δ^2g = genotypic variation

X = Grand mean of the character studied.

Estimation of heritability in broad sense: Broad sense heritability (h^2) expressed as the percentage of the ratio of the genotypic variance (δ^2g) to the phenotypic variance (δ^2p) as described by Allard (1960) as:

$$H^2 = \frac{\delta 2g}{\delta 2p} \times 100$$

Estimation of genetic advance: The genetic advance expressed under selection in broad sense, assuming selection intensity of 5% was estimated in accordance with the methods illustrated by Johnson *et al.* (1995) as:

$$GA = k \times \sqrt{\frac{\delta 2p \times \delta 2g}{\delta 2p}}$$

Where :

GA = expected genetic advance

δ2p = phenotypic variation

δ2g = genotypic variation

k= the standard selection differential at 5% selection intensity (k = 2.063)

Correlation among agronomic traits: Pearson correlations were performed to understand the association among the agronomic traits studied.

RESULTS AND DISCUSSION

Variation among accessions: The analysis of variance for days to maturity, panicle height, panicle width, harvest index, plant height, days to flowering, number of leaves, number of primary panicles, weight of grains per panicle, weight of 100 grains, economic yield, and biological yield indicated significant differences ($p<0.05$) among the genotypes for these traits (Table 2). These results are in conformity with findings of Mohammad *et al*. (2007) who reported significant differences among genotypes of sorghum for economic yield, biological yield and harvest index. Khan *et al*. (2005) also reported similar results in wheat.

Relatively higher genotypic variance values of 794.18, 2587446.8, 726.310, 1045.35 and 548.78 were obtained for number of days to flowering, number of leaves, number of primary panicles, number of days to maturity and weight of grains per panicle, respectively (Table 3). Similarly, the phenotypic variances of these agronomic traits were also high, indicating that the genotype could be reflected by the phenotype and the effectiveness of selection based on the phenotypic performance of these traits could be achieved. Manonmani *et al*. (2002) gave similar reports in red grain sorghum genotypes.

Differences between GCV and PCV for the agronomic traits studied were found to be less indicating that these traits were less affected by environmental fluctuations (Table 3). This is in agreement with the results of Julata *et al*. (2011) and Danquah and Ofori (2012) in vulgare landraces and accessions of garden eggplant, respectively. Desmukh *et al*. (1986) categorized PCV and GCV values into following classes; as high (>20%), medium (10-20%) and low (<10%). In this study, PCV values ranged from 21.39% in number of leaves to 67.40% in number of grains per panicle. The GCV ranged from 20.80% in number of leaves to 67.30% in number of grains per panicle (Table 3). Based on Desmukh *et al*. (1986) classification, the only agronomic trait which recorded medium value for PCV and GCV was number of leaves. However other agronomic traits evaluated recorded values of GCV and PCV well above the medium range. This suggests sufficient genetic variability to facilitate improvement through selection of these agronomic traits. The development of effective breeding programme depends on existence of genetic variability.

Estimates of Heritability: The efficiency with which genotypic variability can be exploited by selection depends upon heritability of individual traits (Bilgin *et al*., 2010). In addition, it gives an indication as to how a given trait or agronomic character will respond to selection (Falconer and Mackey, 1996). In the present study, high heritability value was recorded for Number of days to flowering, number of grains per panicle, number of primary panicles, number of days to maturity, weight of grains per panicle, weight of 100 grains, plant height. Weight of grains per panicle had the highest heritability estimate (99%) followed by plant height (96%) (Table 3). Panicle width had the lowest value (10%) followed by number of leaves (18%). The heritability of harvest index and panicle height were 54% and 78%, respectively.

Table 2. Variation in agronomic traits of sorghum varieties.

Variety	No. of days to maturity	Panicle height (m)	Panicle width (m)	Harvest index	Plant Height (m)	No. of days to flowering	No. of grains per panicle	No. of leaves	No. of prim. panilces	Wt. of grains per panicle	weight of 100 grains	Economic yield	Biological yield
Kadaga	96.75	0.24	0.19	0.27	3.34	56.20	1348	10.00	107.00	49.50	3.76	28.00	105.00
Banina	160.75	0.48	0.22	0.10	4.12	111.50	4766	13.00	93.30	89.70	1.88	41.60	451.00
Naga red	96.00	0.33	0.18	0.05	3.70	56.80	2010	10.00	91.30	84.90	4.27	10.20	204.00
Kapala	95.50	0.26	0.17	0.26	2.14	52.80	1436	8.00	45.80	44.10	3.13	25.70	110.00
LS D (P<0.05)	1.92	0.06	0.03	0.10	0.56	1.01	273.80	1.60	6.20	7.98	0.40	13.20	100.60
SE	1.20	0.37	0.02	0.06	0.35	0.63	171.20	1.01	3.90	4.99	0.25	8.22	62.90
%CV	1.10	11.20	11.30	37.00	10.60	0.90	7.20	10.00	4.60	7.40	7.80	31.20	28.90

Table 3. Genetic parameters yield contributing characters in four varieties of sorghum

Character	GV	PV	EV	GCV	PCV	H2B	GA
Harvest index	0.0114	0.01241	0.00960	63.68	66.30	0.54	0.0138
No. of days to flowering	794.10	794.180	0.0990	40.66	40.66	0.99	1636.0
No. of grains per panicle	2587446.8	2594774	7327.30	67.30	67.40	0.99	5345234.4
No. of leaves	4.43050	4.688000	0.25700	20.80	21.39	0.18	1.6995
No. of primary panicles	726.310	730.0600	3.75300	31.68	31.77	0.99	1496.4
No. of days to maturity	1045.35	1045.710	0.36100	28.80	28.81	0.99	2154.2
Panicle height(m)	0.0117	0.012100	0.00340	33.18	33.65	0.78	0.0194
Panicle width(m)	0.0048	0.005900	0.00011	37.00	40.70	0.10	0.0119
Plant height(m)	0.6960	0.727000	0.03080	25.10	25.70	0.96	1.430
Weight of 100 grains	1.04700	1.063000	0.01600	31.41	31.61	0.99	2.1400
Weight of grains per panicle	548.780	555.1800	6.22000	34.91	35.12	0.99	1132.23

Characters like number of days to flowering, number of grains per panicle, number of primary panicles, number of days to maturity, weight of 100 grains, weight of grains per panicle, plant height and panicle height, besides depicting high GCV and heritability, also exhibited higher genetic advance reflecting the importance of additive gene effects in their inheritance and their expression. Breeding methods based on progeny testing and mass selection could be useful in improving these traits. Association among traits: Yield is the result of combined effects of several component characters and environment. Understanding of the interaction of characters among themselves and with the environment is of great use in plant breeding. Correlation studies provide information on the nature and extent of association between any two pairs of metric characters. Hence it could be possible to bring genetic improvement in one character by selection of the other of a pair.

Most of the agronomic traits evaluated in this study showed positive and significant ($P<0.05$) correlation among themselves. For instance, there was also a positive and significant correlation between number of days to flowering and number of grains per panicle (0.91), number primary panicles (0.99), number of days to maturity (0.94), panicle weight (0.94), panicle width (0.67), weight of 100 grains (0.67), weight of grains per panicle (0.77), economic yield (0.78), biological yield (0.99). Number of leaves and number of primary panicles had positive and significant correlation with number of primary panicles (0.98)(0.89) number of days to maturity (0.98)(0.87),panicle weight (0.91)(0.99), panicle width (0.69)(0.89), plant height (0.87), weight of 100 grains (0.77), and weight of grains per panicle (0.66)(0.75), economic yield (0.68)(0.61) and biological yield (0.99)(0.90). The significant positive correlation among these traits suggests that these traits could be simultaneously improved without any compensatory negative effects. However, negative and significant correlation was observed between harvest index and panicle height (-0.72), plant height (-0.72), weight of grains (-0.96). Also negative and significant correlation was observed between panicle width and plant height (-0.70).

The negative relationship between these traits suggests that they should be improved independently. Similar results for the association of these characters were reported by Veerabadbiran *et al.* (1994) who reported that number of grains/ panicle had positive effect on grain yield. Mahajan *et al.* (2011) and Millinath *et al.* (2004) also reported that days to 50% flowering, panicle length, plant height and number of grains/ panicle were associated among themselves in sorghum.

Principal Components Analysis: Principal Components Analysis of 13 Yield Related Traits is given in (Table 5). The first principal component (PC) alone explained 99.95% of the total variation. The most important character which contributed more to PC1 was the number of grains per panicle (-0.99. This agrees with findings of Gerrano (2010) who also reported that grain number per panicle showed the most variation among characters with high positive loading. Hence due consideration should be given to this character while planning a breeding strategy for increased grain yield in sorghum. The second principal component (PC2) accounted for 0.03% of the total variation and was dominated by traits such as number of primary panicles, and weight of grain per panicle. The contribution of yield related traits among sorghum varieties studied was further explained by the PCA biplot (Figure 1). It was clear from the biplot that number of grains per panicle was associated with *Banina*, a high yielding variety, thus confirming that number of grains per panicle is a high yielding trait.

Table 4. Phenotypic correlation coefficients among yield contributing characters in sorghum.

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13
X_1													
X_2	-0.47												
X_3	-0.59	0.91**											
X_4	-0.54	0.33	0.29										
X_5	-0.31	0.99***	0.98***	0.89**									
X_6	-0.43	0.94**	0.98***	0.87**	0.30								
X_7	-0.72*	0.94**	0.91**	0.99***	0.62	0.93**							
X_8	-0.45	0.67*	0.69*	0.89**	0.84**	0.63	0.74*						
X_9	-0.72*	-0.86**	-0.82**	0.87**	0.08	-0.89**	-0.71*	-0.70*					
X_{10}	-0.06	0.67*	0.77*	-0.61*	0.46	0.64	0.86**	0.68	0.86**.*				
X_{11}	-0.96***	0.77*	0.66*	0.75*	0.13	0.65*	0.51	0.71*	0.21	-0.92***			
X_{12}	0.21	0.78*	0.68*	0.61*	0.12	0.79*	0.86**	0.75*	0.68*	0.68*	0.71*		
X_{13}	-0.67	0.97***	0.99***	0.90**	0.33	0.96***	0.99***	0.90**	0.73*	-0.75*	0.83**	0.59	*

Table 5. Principal Components Analysis of 13 yield Related Traits.

	PC1	PC2	PC3	PC4	PC5
Biological yield	-0.09962	-0.44675	-0.00040	-0.32609	0.14974
Number of days to maturity	-0.00527	0.21224	-0.33761	0.31646	0.18547
Harvest index	0.00004	0.00215	-0.00295	0.00272	-0.00464
No. of days to flowering	-0.01718	0.05332	-0.19449	0.26490	-0.70769
No. of days to maturity	-0.01961	0.11960	- 0.22649	0.28773	0.59228
No. of grains per panicle	-0.99459	0.04894	-0.03800	0.01240	-0.01574
No. of leaves	-0.00120	-0.02433	-0.02991	0.00015	0.08890
No. of primary panicles	-0.00497	-0.73844	-0.65655	0.11100	0.01189
Panicle width	-0.00497	-0.00017	-0.00039	0.00010	0.00035
Plant height	-0.00037	-0.02072	-0.00574	-0.00843	-0.10991
Weight of 100 grains	-0.00052	-0.01934	0.00949	-0.02040	-0.26673
Weight of grains per panicle	-0.01115	-0.43489	0.38268	0.79221	0.00295
Panicle height	- 0.00007	-0.00040	0.00074	0.79221	0.00291
Proportions	99.95	0.03	0.02	0.00	0.00

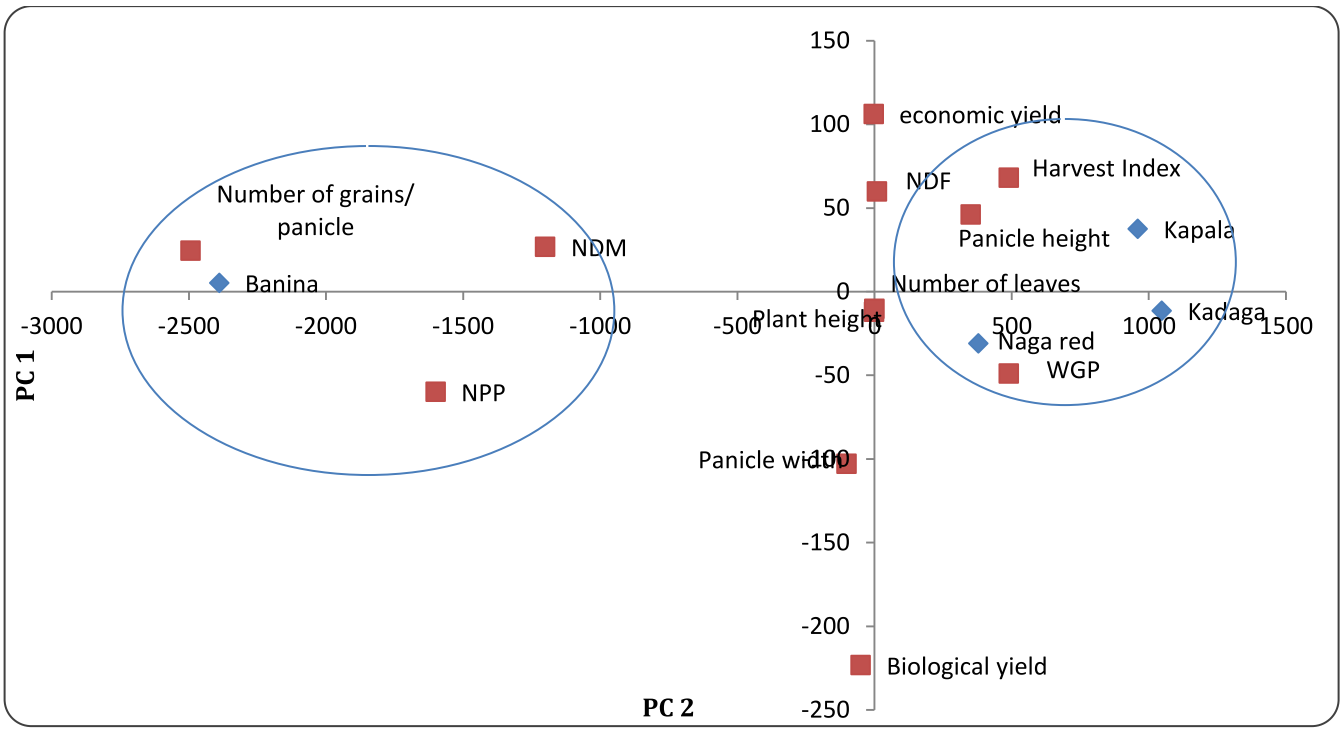

Figure 1. PCA biplot (contribution of yield related traits among sorghum varieties).

CONCLUSION

From the results of this study, it could be concluded that there were significant genetic variability among the accessions of sorghum studied. *Banina* was the highest yielding variety. Most of the traits evaluated were positively associated among themselves and could be improved simultaneously. The genetic variability was more predominant among number of grains per panicle. It further concluded that characters such as number of days to flowering, number of grains per panicle, number of primary panicles, number of days to maturity, weight of 100 grains, weight of grains per panicle, plant height and panicle height combining high GCV, heritability and GA should be considered during selection for yield in sorghum.

ACKNOWLEDGEMENT

The assistance of Mr Kenneth Kambilige, the husband of the second author and Mr Thomas Kanbogha of Ministry of Food and Agriculture (MOFA), Navrongo, during the field work is highly acknowledged.

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