

Full Length Research Paper

Evaluation of yield and yield components of some groundnut genotypes under rainfed condition in Mali using biplot analysis

Ousmane Sanogo^{1,2*}, Pangirayi B. Tongoona¹, Kwadwo Ofori¹, Samuel K. Offei¹ and Haile Desmae²

¹West Africa Centre for Crop Improvement, University of Ghana, P. M. B. 30, Legon, Accra, Ghana.

²International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), BP 320 Bamako, Mali.

Received 28 November, 2018; Accepted 30 October, 2019

Sixteen groundnut genotypes were evaluated under three different environmental conditions of Mali during 2015/2016 rainy season. The environments were Tioribougou, Djijan and Samanko affiliated at International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). The experiments were conducted in a 2x8 alpha lattice with three replications. Within the environment, the main effect of a genotype was significant. Genotypes by environmental interaction were also significant. Results showed that three genotypes ICGX-IS 13005F2-B1-287-1 (grain yield 2,197.1 kg/ha), ICGX-IS 13005F2-B1-205-1 (grain yield 1,922.3 kg/ha) and ICGX-IS 13012F2-B1-29-1 (grain yield 2,106.0 kg/ha) were found to be stable across environments. The genotypes with high pod yield for each specific environment were ICGX-IS 13005F2-B1-287-1 with 2197.1 kg/ha in Tioribougou and ICGX-IS 13005F2-B1-252-1 with 2382.8 kg/ha in Samanko.

Key words: Groundnut, yield, genotype x environment interaction.

INTRODUCTION

Groundnuts are main food product for thousands of small scale farmers in Mali. FAOSTAT (2015) data on groundnut production showed that, for the country, the increase in groundnut production resulted from the expansion of the area cultivated and increase in the number of farmers involved in the production rather than the increase of yield productivity *per se* for more than 50 years. Other studies indicated that severe drought

occurred twenty times during 55 years in Mali (Ndjeunga et al., 2003). Moreover, SAS Institute 2009 argued that in West Africa, groundnut productivity follows similar trends with the rainfall pattern, which is mostly dominated by the occurrence of recurrent drought spells. The groundnut production is rain-fed in Mali and most of the time; the growing phase terminates under a period of drought. This exposes the crop to end-of season drought causing

*Corresponding author. E-mail: ouzbi777@gmail.com. Tel: +223 79180938.

yield loss ranging from 44 to 85% in Mali (Sanogo et al. unpublished). Though, breeding for drought tolerance should be an important objective for breeders in the Sahelian region, Ravi et al. (2011) proposed the development of varieties that are better adapted to water-limited conditions. One of the most important steps in a breeding programme is the assessment of new breeding materials in target environments. Assessing the performance of breeding lines is crucial because it involves both breeders and farmers and allows critical judgments from both sides before the acceptance of the promising lines by farmers. Testing of potential new genotypes in diverse environments can reveal wide adaptation, or yield stability of cultivar, and good mean performance (Simmonds, 1991). According to Kang et al. (2006), genotype-by-environment interaction (GEI) is expected in trials that involve cultivars with diverse genetic backgrounds in diverse test sites. Estimates of significant GEI effects is an indication that genotypes respond differently under different growing conditions, suggesting that environments have effect on the genotypes' performance (Worku et al., 2001). In Sub-Saharan Africa, groundnut breeders generally select genotypes with high pod yield to specific environments. GEI is common under drought situations (Bänziger et al., 2004), and drought events are unpredictable and occur randomly. In a GEI study across Niger and India, Hamidou et al. (2012) observed a high GEI between the two countries suggesting the need for environment-specific selection in groundnut. The present study was designed to assess the new developed drought tolerant groundnut lines along with their four parental lines and the two landraces and to identify promising genotypes across three different locations in Mali. The specific objectives were to: (i) determine the importance of genotype x environment interaction in the different genotypes, (ii) identify varieties with stable performance or specific adaptation to be recommended to farmers in Mali for cultivation.

MATERIALS AND METHODS

Genetic material

Sixteen genotypes comprising 10 $F_{2:4}$ drought tolerant groundnut and six controls (4 parental lines and 2 landraces) were evaluated in this study (Table 1).

Field location and experimental conditions

The ten superior elites genotypes and their four parents were evaluated at Tioribougou (580 m above sea level masl, latitude 13°22' N, longitude 7°69' W), Djijan (320 m asl latitude 13°05' N, longitude 9° 28' W) and Samanko ICRISAT Research Station (331 m, latitude 12°54'N, longitude 8°40'W), during the rainy season 2015/2016. The average annual rainfall at Tioribougou, Djijan and Samanko affiliated with ICRISAT are 700, 900 and 800 mm, respectively. Currently, two local controls: 47-10 and Tigaba which

are the most popular in Mali were included. All experiments were laid out as 8x2 alpha lattice designs with 3 replications. Each plot consisted of a row with a length of 4 m with 60 cm within-row spacing and 15 cm between-row spacing. Prior to planting, basal fertilizer was applied as 100 kg ha⁻¹ Simple Super phosphate. Standard cultivation practices, including hand planting, hand weeding.

Data collection and analysis

Data collected included: 50% flowering [50%DF] (in days), Biomass weight [BIO] (g), Pod Yield [PY] (kg/ha), one hundred seed weight [HSW] (g), Shelling percentage [SP] (%), Harvest index [HI], and Grain Yield [GY] (kg/ha).

Data were analyzed in analysis of variance (ANOVA) across locations using PROC GLM in SAS (SAS Institute, 2009). Replications, Environments' and incomplete blocks were considered as random effects while genotypes were considered as fixed effects. PROC CORR was used to perform correlation analysis. The GGE biplot analysis (Yan and Tinker, 2006) was performed using GenStat software Edition 15 for grain yield means adjusted for block effects to obtain information on the genotypes in the three experimental environments. It was also applied to estimate genotypic mean performance across environments for stability analysis. GGE biplot analysis allows the disintegration of the G x E interactions. The first two principal components (PC1 and PC2) were constructed in GGE biplot that were derived from subjecting environment-centered grain yield means for each location to singular value disintegration. The data were not transformed ('Transform=0'), but standardized ('Scale=1), and were environment-centered (Centering=2).

RESULTS

Mean squares from ANOVA for yield and drought traits in 16 groundnut lines

Results of the analyses of variance combined across environments and for each environment are presented in Table 2. ANOVA revealed highly significant ($P<0.01$) effects of genotypes for 50%flowering, hundred seed weight, harvest index, shelling percentage whereas genotypes effects were significant ($P<0.5$) for pod and grain yield (Table 2). Environment effects were highly significant ($P<0.01$) for 50% flowering, hundred seed weight, harvest index, shelling percentage, pod yield and grain yield (Table 2).

Environmental mean performance and coefficient of variation of traits in 16 genotypes

By comparing the three environments for their mean performance across the 16 genotypes, higher values were recorded in Djijan compared to Tioribougou and Samanko for most of the traits except for 50% DF, pod yield and grain yield (Table 3). Fifty percent date to flowering of plants ranged from 25 days in Tioribougou and Samanko to 26 days in Kita. Biomass production varied from 290 g in Djijan to 172.20 g in Samanko.

Table 1. Groundnut genotypes use for the GEI experiment in three environments in Mali, 2015.

ID	Genotype	Pedigree	Source	Status
G1	ICGX-IS 13005F2-B1-205-1	ICGV 91317/ICGV 87378	ICRISAT	F ₄
G2	ICGX-IS 13005F2-B1-252-1	ICGV 91317/ICGV 87378	ICRISAT	F ₄
G3	ICGX-IS 13005F2-B1-287-1	ICGV 91317/ICGV 87378	ICRISAT	F ₄
G4	ICGX-IS 13005F2-B1-46-1	ICGV 91317/ICGV 87378	ICRISAT	F ₄
G5	ICGX-IS 13005F2-B1-91-1	ICGV 91317/ICGV 87378	ICRISAT	F ₄
G6	ICGX-IS 13012F2-B1-29-1	ICIAR 19BT / ICGS 44	ICRISAT	F ₄
G7	ICGX-IS 13012F2-B1-297-1	ICIAR 19BT / ICGS 44	ICRISAT	F ₄
G8	ICGX-IS 13012F2-B1-40-1-1	ICIAR 19BT / ICGS 44	ICRISAT	F ₄
G9	ICGX-IS 13012F2-B1-525-1	ICIAR 19BT / ICGS 44	ICRISAT	F ₄
G10	ICGX-IS 13012F2-B1-576-1	ICIAR 19BT / ICGS 44	ICRISAT	F ₄
G11	ICIAR 19BT	Introduced control [§]	ICRISAT	P ₁
G12	ICGS 44	Introduced control	ICRISAT	P ₂
G13	ICGV 87378	Introduced control	ICRISAT	P ₃
G14	ICGV 91317	Introduced control	ICRISAT	P ₄
G15	47-10	Landrace (control)	Mali	P ₅
G16	Tigaba	Landrace (control)	Mali	P ₆

F₄=F₂-derived F₄ progenies. P₁ to P₄= parents used as introduced controls; P₅ and P₆= local controls.

Table 2. Mean squares for yield and yield components in 16 groundnut lines, evaluated across three environments in Mali.

Source of variation	df	50%DF	BIO	HI	HSW	SP	PY	GY
GENOTYPE (G)	15	70.70***	9.43*	24.11***	16.69***	26.54***	5.47*	6.34*
ENV (E)	2	0.38***	1.66***	2.02***	0.45***	1.21	0.17***	0.24***
REP(ENV)	4	0.47	2.49*	2.24*	3.14**	4.39*	1.95*	1.46*
G x E	30	10.05**	15.38*	21.08*	9.64**	34.59***	10.36*	12.10*
ERROR	90	13.58	30.79	38.36	11.21	33.13	29.16	32.92

*, **, *** implies $P \leq 0.5$, $P \leq 0.01$ and $P \leq 0.001$, respectively; Rep = Replication, DTF=Date to 50% flowering, BIO = biomass production, HI = harvest index, HSW=hundred seed weight, SP = shelling percentage, PY = pod yield, GY = grain yield.

Harvest index ranged between 79.30% in Tioribougou and 67.70% in Samanko. Hundred seed weight ranged from 29.50 g in Samanko to 40.90 g in Djijan. Shelling percentage ranged between 73.90% in Samanko and 74.20% in Djijan and Tioribougou. The overall mean of groundnut pod yield was variable between 1,868 kg/ha in Samanko and 3,406.74 kg/ha in Djijan. Grain yield ranged from 1,980.50 kg/ha in Samanko to 2,365 kg/ha in Tioribougou. Coefficient of variation obtained ranged from 2.32% for SP in Tioribougou to 28.08% for GY in Djijan. The low yielding environment (Samanko) exhibited lower coefficient of variation for several characters than the two higher yielding environments (Djijan and Tioribougou) (Table 3).

Correlation of grain yield and other traits between locations

In Djijan, grain yield had positive and highly significant

correlation ($P < 0.001$) with pod yield ($r = 0.78$), biomass ($r = 0.53$) and harvest index ($r = 0.38$) (Table 4). Likewise in Tioribougou, highly significant ($P < 0.001$) correlation existed between grain yield and pod yield ($r = 0.95$), biomass ($r = 0.49$) and harvest index ($r = 0.38$). Across the three environments, highly significant ($P < 0.001$) and positive correlation occurred between grain yield, biomass ($r = 0.70$), harvest index ($r = 0.40$), 100-seed weight ($r = 0.58$) and pod yield ($r = 0.90$) (Table 4).

GGE biplot analysis

Figures 1 to 3 provide graphical results of the GGE biplot analysis. The GGE biplot of the grain yield of the 96 genotypes revealed that PC1 explained 61% of the total variation while PC2 explained 28%. The total variation for grain yield of the genotypes across the three environments account for 89% with PC and PC2 (Figure 1). The GGE biplot was based on genotype-metric

Table 3. Environmental means performance, coefficient of variation of studied traits of 16 genotypes evaluated in Mali.

Trait	Djjan			Tioribougou			Samanko			Across locations		
	Mean ± SE	CV (%)	R ²	Mean ± SE	CV (%)	R ²	Mean ± SE	CV (%)	R ²	Mean ± SE	CV (%)	R ²
50% DF	26 ± 0.4	6.11	0.84	25.6 ± 0.4	4.88	0.88	25 ± 0.4	3.98	0.91	26 ± 0.2	5.14	0.86
BIO	290.8 ± 10.7	22.73	0.54	262.4 ± 8.5	19.46	0.57	172.2 ± 7.5	22.74	0.67	241.8 ± 6.7	23.13	0.69
HI	69.4 ± 1.9	17.15	0.54	79.3 ± 1.8	12.54	0.63	67.7 ± 2.3	18.31	0.64	72.1 ± 1.2	15.91	0.62
HSW	40.9 ± 0.7	9.19	0.69	40.4 ± 0.6	6.34	0.77	29.5 ± 0.6	6.22	0.88	36.9 ± 0.6	7.83	0.89
SP (%)	74.2 ± 0.6	4.58	0.61	74.2 ± 0.4	2.32	0.82	73.9 ± 0.5	3.14	0.73	74.1 ± 0.3	3.45	0.67
PY	3309.2 ± 121.3	24.36	0.47	3406.74 ± 97.2	21.83	0.30	1868.0 ± 62.9	18.77	0.63	2861.3 ± 80.9	23.09	0.71
GY	2231.3 ± 91.3	28.08	0.44	2365.0 ± 68.8	21.38	0.35	1345.2 ± 41.3	17.26	0.62	1980.5 ± 55.2	24.21	0.67

[§]Mean and SE of studied traits in three locations and across. 50% DF = Date to 50% flowering, 50% DF = Day to 50% flowering (days), HSW = hundred seed weight (g), SP = Shelling percentage (%), PY = pod yield (kg ha⁻¹), GY = grain yield (kg ha⁻¹), CV (%) = Coefficient of Variation, R² = R-square.

Table 4. Person correlation coefficients of grain yield of 16 groundnut genotypes with other traits at Djijan, Tioribougou, Samanko, and across environments.

Trait	Djjan	Tioribougou	Samanko	Across locations
50% date to flower	-0.13*	-0.11*	0.14*	0.08*
Biomass	0.53***	0.49**	0.55***	0.70***
Harvest index	0.38***	0.43**	0.27	0.40***
100-Seed weight	0.06***	-0.01	0.31*	0.58***
Shelling per cent	0.27*	0.14*	0.07	0.15*
Pod yield	0.78***	0.95***	0.94***	0.90***

*, **, *** implies P ≤ 0.5, P ≤ 0.01 and P ≤ 0.001, respectively; 50% DF = Date to 50% flowering (days), Biomass (kg), SLAz = Specific leaf area (cm² g⁻¹) at 80 DAS, 100 seed weight (g), SP = Shelling percent (%), PY = pod yield (kg ha⁻¹).

preserving (SVP = 1) which is more appropriate for comparing genotypes. Genotypes ICGX-IS 13005F2-B1-287-1 (G3) and ICGX-IS 13005F2-B1-205-1 (G1) were higher yielding while genotypes ICIAR 19BT (G11) and ICGX-IS 13005F2-B1-252-1 (G2) were the lowest yield performers and their absolute higher PC2 scores were associated with genotypic instability (Figure 1). The genotype ICGX-IS 13012F2-B1-297-1 (G6) was the most stable across the three environments based on its PC1 score and PC2 near-zero.

Genotypes ICGX-IS 13005F2-B1-287-1 (G3), ICGX-IS 13005F2-B1-205-1 (G1) and ICGX-IS 13012F2-B1-29-1 (G6) had the highest mean performance in the three experimental environments (Table 5). The absolute length of the projection of a genotype onto the Average Genotypic Ordinate (single blue line, a horizontal line passing through the origin of the biplot on the y-axis) is a measure of its stability. The shorter the projection, the more stable is the yield performance of the genotype. Thus, the genotypes ICGX-IS 13012F2-B1-297-1 (G7), ICGV 87378 (G13) and ICGX-IS 13012F2-B1-29-1 (G6) were the most stable in the three experimental environments (Figure 2). Among all, the "ideal" genotype was ICGX-IS 13005F2-B1-287-1 (G3) located in the centre of the circle (Figure 3). The desirable genotypes

were ICGX-IS 13005F2-B1-205-1 (G1) and ICGX-IS 13012F2-B1-29-1 (G6) while the undesirable ones were ICGS 44 (G12), ICGX-IS 13005F2-B1-91-1 (G5) and Tigaba (G16). The three environments were classified as follows: Tioribougou > Djijan > Samanko in discriminating genotypes for grain yield (Figure 3). Overall, the "ideal genotype" and the desirable ones were the new developed drought tolerant genotypes. Also, the highest yielding as well as the most stable genotypes belongs to the new genotypes. It is important to confirm the superiority of the new drought tolerant genotypes over the six controls (four parents and two landraces) since the genetic material was evaluated in one season.

DISCUSSION

The first objective of this study was to evaluate genotypes to random drought. Drought is, though not predictable but occurs frequently in Mali. However, rainfall patterns during the period of the experiment from planting to harvesting across the three environments were favorable for plant growth. As a result, there was no drought spell affecting the crop during the reproductive phase. Hence the true potentials of the newly developed

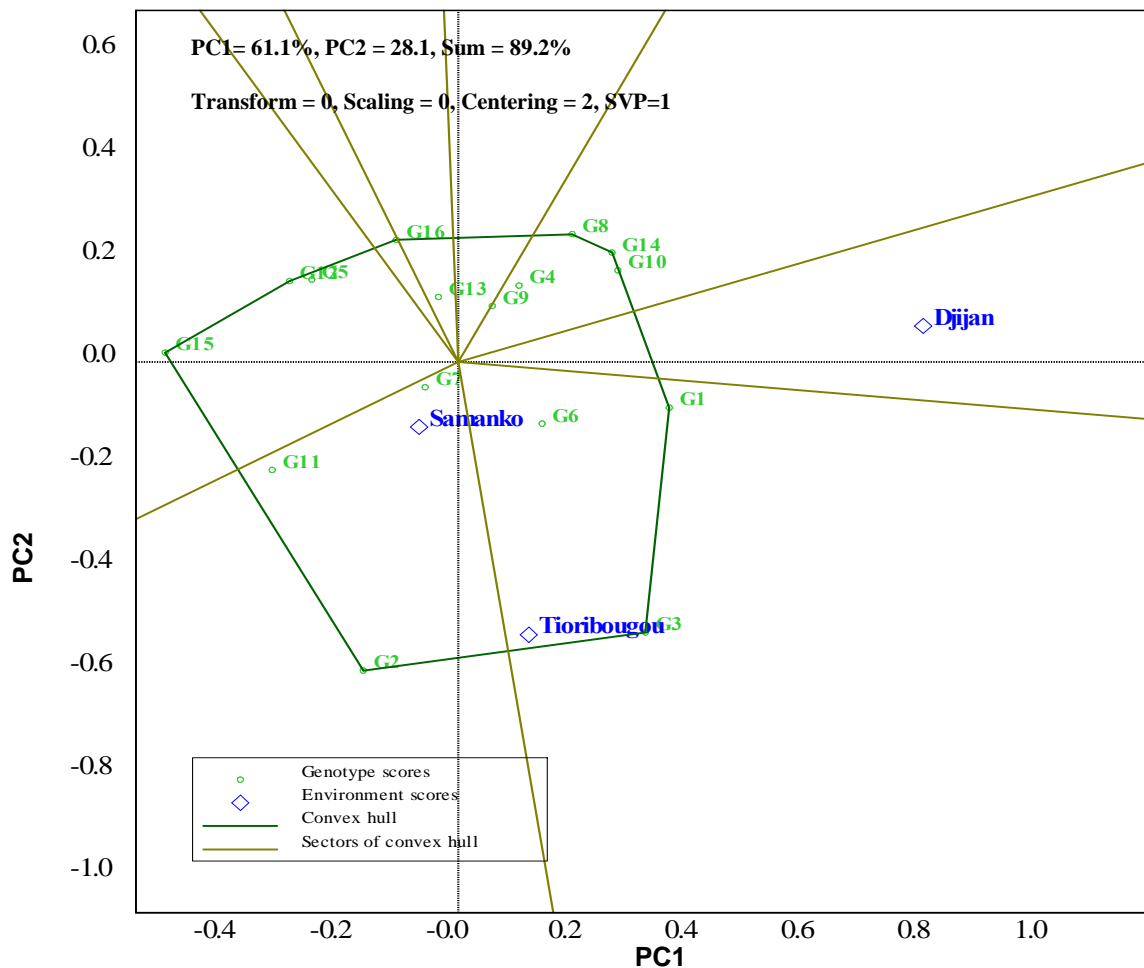


Figure 1. The "Which-Won-Where" GGE biplot based on groundnut grain yield data of 16 genotypes in three environments (Djijan, Tioribougou and Samanko).

lines under drought are yet to be determined. Therefore the testing of the lines under controlled drought conditions is necessary to confirm the presence of drought tolerance alleles in the newly developed lines. In the present study, correlations were calculated in each environment separately and also based on the mean values obtained from the pooled analysis. The 50% DF and hundred seed weight were correlated with grain yield in one environment but not in other environment indicating that environment might have some influence. Therefore, selection of these traits would need attention for further characterization and improvement. This suggests that these traits are not stable across environments and are therefore unreliable as secondary traits for genetic improvement of grain yield. Pod yield, shelling percentage, harvest index and biomass production exhibited a positive and significant (<0.5) phenotypic correlation with grain yield in all the environments or at least two environments indicating selection of these traits will simultaneously improve the

yield. Similar results were obtained by Sharma and Varshney (1995), Johnson et al. (2008) and Ravi Kumar et al. (2012) who reported a significant and positive correlation of grain yield with pod yield. Wunna et al. (2009) detected strong correlation between grain yield and shelling percent, biomass production. The results from the current study were not in agreement with other findings such as those reported by Uddin et al. (1995) who found negative correlation between 100-seed weight and grain yield while Sumathi and Ramanathan (1995) and Sah et al. (2000) showed positive correlation between 100-seed weight and grain yield in groundnut. The correlation between grain yield and several characters in groundnut were reported by a number of investigators. For example, Sharma and Varshney (1995), Johnson et al. (2008) and Ravi Kumar et al. (2012) reported significant and positive association of grain yield with pod yield. Wunna et al. (2009) detected strong correlation between grain yield and shelling percent, biomass production. The results of the current

Table 5. Mean performance of 10 F_{2:4} drought tolerant genotypes and the 6 controls in the three experimental environments for studied traits in Mali.

Genotype	50%DF	BIO	HI	HSW	SP	PY	GY
F_{2:4} genotypes							
G1	26	197.0	78.8	38.7	0.8	2602.9	1922.3
G2	28	242.6	79.8	36.2	0.8	3278.5	2382.8
G3	24	219.3	86.1	36.6	0.8	3140.8	2197.1
G4	28	257.3	66.6	34.4	0.8	2803.6	1973.4
G5	25	244.6	75.0	33.4	0.8	3072.4	2119.0
G6	24	255.9	70.0	33.9	0.7	2984.4	2106.0
G7	23	240.0	71.4	37.4	0.7	2822.3	2050.9
G8	24	257.0	69.8	38.1	0.8	2913.1	1976.1
G9	23	266.8	72.1	37.2	0.7	3115.8	2086.0
G10	23	225.2	65.8	34.8	0.8	2466.3	1804.9
Mean of F _{2:4}	25	240.6	73.5	36.1	0.8	2920.0	2061.8
Controls							
G11	24	236.8	79.2	33.6	0.7	3020.7	1808.2
G12	29	193.6	78.2	37.7	0.7	2542.8	1753.7
G13	25	242.1	67.7	38.1	0.7	2722.2	1894.5
G14	25	276.9	64.1	36.9	0.8	2905.7	1990.1
G15	31	283.9	55.8	45.2	0.7	2632.2	1771.7
G16	29	230.2	73.8	39.2	0.7	2757.4	1851.7
Mean control	27	243.9	69.8	38.4	0.7	2763.5	1845.0
Overall							
Mean	26	241.8	72.1	37.0	74.1	2861.3	1980.5
SE±	0.2	6.7	1.2	0.6	0.3	80.9	55.2
CV (%)	5.1	23.1	15.9	7.8	3.5	23.1	24.2
R ²	0.9	0.7	0.6	0.9	0.7	0.7	0.7
Contrast: F _{2:4} vs Controls	***	ns	ns	*	**	ns	*

ns = non-significant, *P<0.05, **P<0.01, ***p<0.0001, respectively. 50% DF= Day to 50% flowering (days), SCMRf = SPAD meter reading at 60 DAS, SCMRz = SPAD meter reading at 80DAS, SLAf = Specific leaf area (cm² g⁻¹) at 60 DAS, SLAz = Specific leaf area (cm² g⁻¹) at 80 DAS, HSW = hundred seed weight (g), SP = Shelling percentage (%), PY= pod yield (kg ha⁻¹)and GY = grain yield (kg ha⁻¹).

study have some implications in breeding for agronomic and yield components traits in groundnut in Mali. Grain yield associated negatively with 50% DF suggests delayed crop growth may reduce grain yield. This is probably because of the possibility that the crop may be exposed to several prevailing abiotic stresses like drought and thereby reducing yield (Nagabhusanam, 1981). This scenario should be avoided in the major groundnut cultivation areas in Mali such as Kolokani by selecting drought tolerant materials or short duration varieties. The correlation between grain yield and other yield components indicated that possible superior segregants could be selected in combinations of traits such as days to 50% flowering, hundred seed weight and shelling percentage. The multi-environmental trial analyses conducted in three locations Dijjan, Tioribougou and Samanko revealed that genotypes, environments

and their interactions were significant for almost all traits which agreed with a number of previous results such as Nath and Alam (2002), Bucheyeki et al. (2008), Hamidou et al. (2012) and Makinde et al. (2013) working on groundnut. Both of genotypic and environmental differences played important roles in the expression of the different traits with significant GEI reflected in combined analysis. The genotypes revealed a considerable variability for agronomic traits and yield components that could be potentially useful for the improvement of drought related traits as well as yield components. The combined analysis across the three locations for the F₄ progenies compared to the checks revealed improvements made in some traits of interest. This may be due to new genetic combinations produced in the hybridization process. It is important to note that the ten elites genotypes were selected as the top 10 F₄

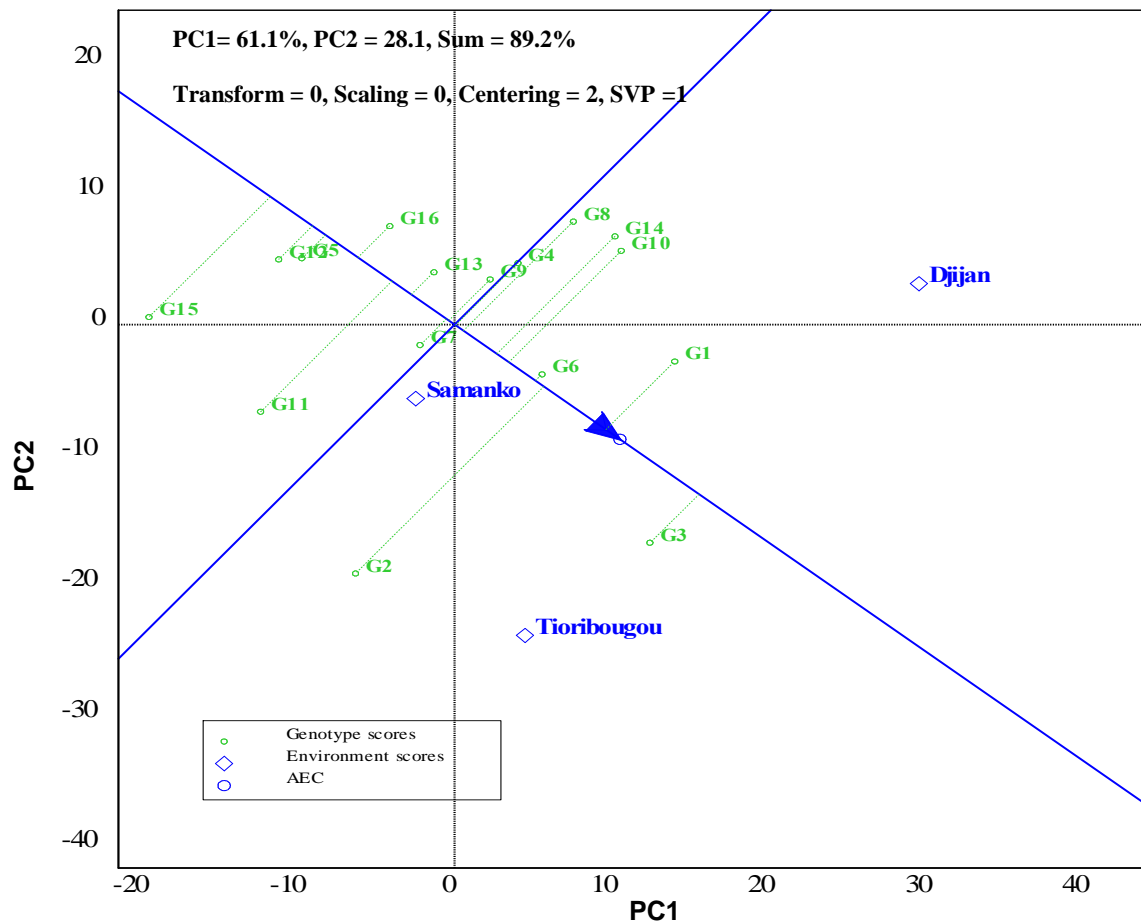


Figure 2. GGE biplot based on groundnut grain yield performance and stability for 16 genotypes in three environments (Djijan, Tioribougou and Samanko).

high performance among 90 drought tolerant genotypes in the breeding process.

Each of the ten F_4 genotypes had a good yield compared to controls and the farmers' best control (Tigaba) in the three experimental condition except ICGX-IS 13012F2-576-1. Four genotypes (ICGX-IS 13005F2-205-1, ICGX-IS 13005F2-252-1, ICGX-IS 13005F2-91-1 and ICGX-IS 13012F2-29-1) were identified with significantly higher pod yield compared to the best control (ICIAR 19BT). The best F_4 genotype (ICGX-IS 13005F2-252-1) with 3,278.80 kg/ha represented 24.5% higher yield than the best control ICIAR 19BT. Farmers normally adopt varieties that yield more than their locally adapted cultivars; and meet the preferred traits which differ from one community to another (Gowda et al., 2000). The selection criteria of variety largely depend on the importance of the crop in the farming system and their uses (Abebe et al., 2005). Genotypes out yielding with more than 20% over landraces open the possibility of introduction or replacing with the landrace Tigaba, a late maturing variety. Tigaba

cannot be cultivated in low falling periods or drought years. The variety 47-10, the most widely grown variety in Mali, produces a lot of pods with few seeds resulting in low yield. In addition to that, the variety is suspected to have high aflatoxin levels which is damaging to humans and cattle when consumed. These new genotypes should be evaluated for other farmers and end-users before adoption. Each of the ten F_4 genotypes had a good yield performed well compared to mean controls and the farmers' best check (Tigaba) except ICGX-IS 13012F2-576-1. The genotype-by-environment interactions effects on pod yield were significant. Genotype-by-environment interaction effects on pod yield have been reported in a number of previous studies but the most recent results from Bucheyeki et al. (2008), Jogloy et al. (2009), Zhang et al. (2011), Balota et al. (2012) and Makinde et al. (2013) were consistent with the present results. The presence of genotype by environment interactions resulted in the yield performance of genotypes and ranking of genotypes varying from one environment to another, which suggests that environment specific varieties could be selected.

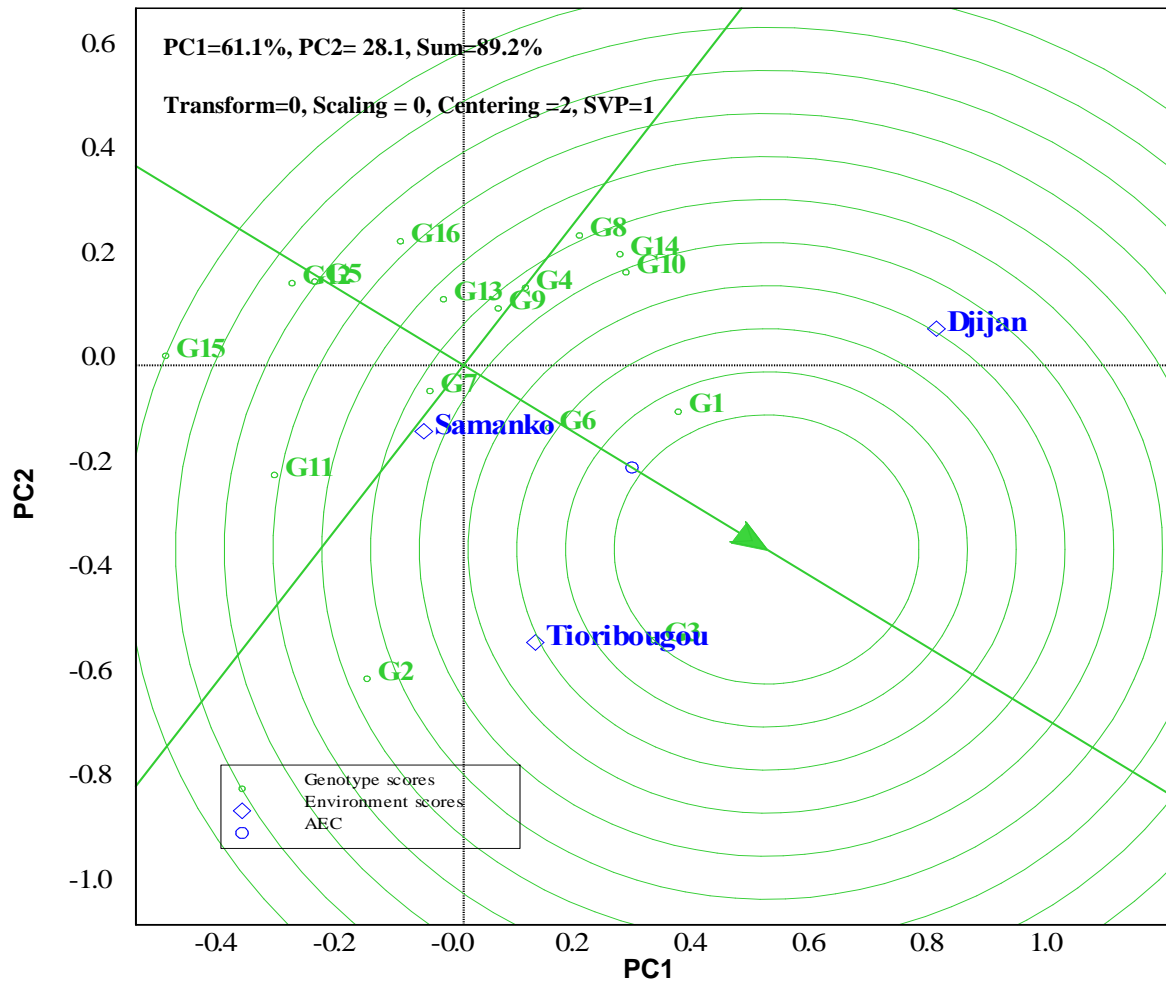


Figure 3. GGE-biplot based on genotype-focused scaling for comparison the genotypes with the ideal genotype across three environments (Djijan, Tioribougou and Samanko).

Genotypes that has significantly a better yield than the controls were identified specifically for each environment including ICGX-IS 13005F2-B1-287-1 (G3) for Tioribougou, ICGX-IS 13005F2-B1-205-1 (G1), ICGX-IS 13005F2-B1-252-1 (G2) for Samanko and ICGX-IS 13012F2-B1-29-1 (G6) for Djijan. In the three experimental environments, genotype ICGX-IS 13012F2-B1-29-1 (G6) whereas ICGX-IS 13005F2-B1-205-1 (G1) and ICGX-IS 13005F2-B1-287-1 (G3) had high yield and high stability.

Conclusion

The genotype by environment interaction influenced drought and traits related to yield or yield components. Some environments were better than others in the expression of the quantitative traits. The difference in ranking genotypes based on yield performance across

the three environments confirmed the presence of the genotype by environment interactions. The genotype by environment interaction analysis using GGE biplot method was powerful to visually analyze the yield performance of genotypes in the three locations. Genotypes that performed significantly better than the checks were identified specifically for each environment including ICGX-IS 13005F2-B1-287-1 (G3) for Tioribougou and ICGX-IS 13005F2-B1-252-1 (G2) for Samanko. Genotypes showing little crossing-over interactions and great potentials for high genetic gains were ICGX-IS 13012F2-B1-29-1 (G6), ICGX-IS 13005F2-B1-205-1 (G1) and ICGX-IS 13005F2-B1-287-1 (G3). Six new drought tolerant genotypes had a good yield of up to 18% over the six controls and three of the same genotypes showed yield superiority of 36% six checks. Increase in yield of the new drought tolerant genotypes over the controls showed substantial achievement in breeding for tolerance to drought. The new genotypes will

contribute to enhancing the production of groundnut in Mali especially in these areas experiencing cycles of drought. Despite these substantial results, further generations and evaluations will enable better homogeneity (fixation of alleles) of lines and clear varietal recommendations to farmers.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

- Abebe G, Assefa T, Harrun H, Mesfine T, Al-Tawaha AM (2005). Participatory selection of drought tolerant maize varieties using mother and baby methodology: A case study in the semi arid zones of the central rift valley of Ethiopia. *World Journal of Agricultural Sciences* 1:22-27.
- Balota MT, Isleib G, Tallury S (2012). Variability for drought related traits of Virginia-type peanut cultivars and advanced breeding lines. *Crop Science* 52:2702-2713.
- Bänziger M, Setimela PS, Hodson D, Vivek B (2004). Breeding for improved drought tolerance in maize adapted to southern Africa "New directions for a diverse planet". Proceedings of the 4th International Crop Science Congress, 26 Sep - 1 Oct 2004, Brisbane, Australia.
- Bucheyeki TL, Shenkalwa EM, Mapunda TX, Matata LW (2008). On-farm evaluation of promising groundnut varieties for adaptation and adoption in Tanzania. *African Journal of Agricultural Research* 3(8):531-536.
- FAOSTAT (2015). Statistical Database of the Food and Agriculture of the United Nations. Online. Available at <http://www.fao.org> on 23 November 2016.
- Gowda BS, Halaswamy BH, Seetharam A, Virk DS, Witcombe JR (2000). Participatory approach in varietal improvement: A case study in finger millet in India. *Current Science* 79:366-368.
- Hamidou F, Ratnakumar P, Halilou O, Mponda O, Kapewa T, Monyo E, Faye I, Ntare BR, Nigam SN, Upadhyaya HD, Vadez, V (2012). Selection of intermittent drought tolerant lines across years and locations in the reference collection of groundnut *Arachis hypogaea* L. *Field Crops Research* 126:189-199.
- Jogloy PS, Vorasoot N, Akkasaeng C, Kesmala T, Patanothai A (2009). Variability in yield responses of peanut *Arachis hypogaea* L. genotypes under early season drought. *Asian Journal of Plant Sciences* 8:254-264.
- Johnson K, Vasanthi RP, Venkateswarlu O (2008). Estimates of genetic parameters and character association in F2 segregating populations of Spanish x Virginia crosses of groundnut (*Arachis hypogaea* L.). *Legume Research* 314:235-242.
- Kang MS, Aggarwal VD, Chirwa, RM (2006). Adaptability and stability of bean cultivars as determined via yield-stability statistic and GGE biplot analysis. *Journal of Crop Improvement* 151:97-120.
- Makinde SCO, Ariyo OJ, Akinbowale RI (2013). Assessment of groundnut performance in different environments using Additive Main effects and Multiplicative Interaction AMMI model. *Canadian Journal of Plant Breeding* 12:60-66.
- Nagabhushanam GVS (1981). Studies on the estimates of genotypic and phenotypic variability and analysis of character association in certain Spanish and Valencia genotypes of groundnut (*Arachis hypogaea* L.). Master Thesis APAU, Hyderabad, India.
- Nath UK, Alam MS (2002). Genetic variability, heritability and genetic advance of yield and related traits of groundnut (*Arachis hypogaea* L.). *Journal of Biological Sciences* 2:762-764.
- Ndjeunga J, Ntare BR, Waliyar F, Echekwu CA, Kodio O, Kapran I, Diallo AT, Amadou A, Bissala HY, Da Sylva A (2003). Early adoption of modern groundnut varieties in West Africa. Working Paper Series no. 24. International Crops Research Institute for the Semi-Arid Tropics 62 p.
- Ravi Kumar D, Sekhar MR, Reddy KR, Ismail S (2012). Character association and path analysis in groundnut (*Arachis hypogaea* L.). *International Journal of Applied Biology and Pharmaceutical* 31:385-389.
- Sah JN, Kumar R, Varshney RK (2000). Correlation and path analysis in mutant cultivars of groundnut. *Journal of Oilseeds Research* 17:23-28.
- SAS Institute (2009). SAS Proprietary Software Release 9.3. SAS Institute, Inc., Cary, NC.
- Sharma VK, Vershney SK (1995). Analysis of harvest index in groundnut. *Journal of Oilseed Research* 12:171-175.
- Simmonds NW (1991). Selection for local adaptation in a plant breeding programme. *Theoretical and Applied Genetics* 82:363-367.
- Sumathi R, Ramathan T (1995). Correlation and path analysis in F3 and F4 generations of interspecific crosses in groundnut. *Madras Agricultural Journal* 82:435-439.
- Uddin MJ, Chowdhary, MAZ, Sultan MK, Mitra BN (1995). Genetic variability, correlation and path analysis in groundnut. *Bangladesh Journal of Scientific and Industrial Research* 30:235-241.
- Worku M, Zelleke H, Taye G, Tolessa LB, Wolde AW, Guta A, Tuna H (2001). Yield stability of maize *Zea mays* L. genotypes across locations. Seventh Eastern and Southern Africa Regional Maize Conference 11-15 February, pp. 139-142.
- Wunna H, Jogloy S, Toomsan B, Sanitchon J, Patanothai A (2009). Inheritance of traits related to biological nitrogen fixation and genotypic correlation of traits related to nitrogen fixation, yield and drought tolerance in peanut *Arachis hypogaea* L. under early drought. *Asian Journal of Plant Sciences* 84:65-75.
- Yan W, Tinker NA (2006). Biplot analysis of multi-environment trial data. Principles and applications. *Canadian Journal of Plant Science* 86:623-645.
- Zhang X, Han S, Tang F, Xu J, Liu H, Yan M (2011). Genetic analysis of yield in peanut *Arachis hypogaea* L. *African Journal of Biotechnology* 10:7126-7130.