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Genotype-Environment (GxE) interaction on cashew (*Anacardium occidentale* L.) cultivar productivity components in Benin

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The aim of this study was to compare the behavior of different cashew in two environments in Benin over a period of four years. The study consisted of monitoring the phenology and productivity of four cashew genotypes during four consecutive cropping seasons (2013-2014; 2014-2015; 2016-2016 and 2016-2017) in the villages of Adourékoman, and Founga. These four cashew genotypes were selected according to their agro-morphological characteristics. A total of 36 trees were used in an experimental design laid at randomized complete block in each site for data collection. Phenology of the tree and yield components were the data collected and submitted to analysis of variance (ANOVA), additive main effects and multiplicative interaction (AMMI), heritability, stability and Pearson correlation using ARiS software. The results of the variance analysis of the phenology and reproductive data showed a significant (P<0.05.) influence of environment on the cashew's parameters studied. The results also showed that North-west presented the higher nut weight (5.83 kg/tree) compared to the Central (1.67 kg/tree) region and the highest nut weight was recorded intree with small fruit and red colour (M2R). The lowest nut weight was observed in the Centre with the genotype having big fruit and yellow colour (M1Y) (1.53 kg/tree). However, the most stable genotype in the two environments was the genotype having big fruit and yellow colour (M1Y). The nut and apple circumference were positively and highly correlated (r=0.616; P<0.001). There were significant differences in rankings of the genotypes at the two environments for all variables. The phenology and reproductive data revealed a significant influence of environment on cashew parameters studied. It was recommended to undertake hybridization between M2R with another variety of cashew for the improvement of cashew productivity in Benin.

Keywords: AMMI, Cashew, phenology, phenotype, heritability, stability, performance

INTRODUCTION

Cashew (*Anacardium occidentale* L.) is a nut tree with multiple usages generally grown in the tropical region to solve economic, social and environmental problems (Yabi*et al.,* 2013; Balogoun *et al.,* 2014). After cotton, cashew nuts highly contribute to export in Benin. The low productivity (0 – 5kg/tree/year) has been reported in several farmers' fields in the Central, Southern and North-Western parts of Benin due to the aging of the cashew and lack of improved cashew cultivars (Bello *et al.,* 2016). Henceforth, the local cashew trees in farmers' fields nowadays are progenies of inferior genotypes. Most of the cashew trees in the country, particularly from the potential growing areas, are very old and necessitate to be improved. Despite that there are some growing young trees; most of them are still from the unimproved old varieties.

It was also noticed that environment plays an important role in the plant production. Desai *et al.* (2010) defined Genotype x Environment (G x E) interaction (GEI) as the failure of genotypes to achieve the same relative performance in different environments. However, in most cases, breeders look for a variety that best performs over a wide array of environments, years and the concept of stability is most of times overlooked. GEI is a challenge to plant breeders, agronomists, and crop producers due to difficulties in selecting genotypes that perform well over diverse environments (Acikgoz *et al.,* 2009). One of the most efficient statistical tools for testing stability across environments is additive main effect and multiplicative interaction (AMMI) analysis (Aliyu *et al.,* 2014). This analysis can help to identify genotypes which have high productivity and well adapted to an agronomic zone, with the aim of regionalized recommendation (Gauch *et al.,* 2011; Gauch, 2013). The performance of a particular cultivar is the result of its genetic constitution and the environment in which it grows. In practice, it is quite possible the same cultivar may not exhibit the same phenotypic performance under different environments. When G x E interaction occurs, factors present in the environment (temperature, rainfall, air humidity, sunshine, harmattan, etc.), as well as the genetic constitution of an individual (genotype), influence the phenotypic expression of a trait.

An understanding of genotype x environment interaction can therefore help to identify traits that contribute to a good cultivar performance and environments that facilitate cultivar evaluation (Yan and Hunt, 2002). Multi-environment trials are being utilized in such situations that ultimately help in selecting the most suitable genotypes (Smith *et al.,* 2005) for an environment. Gene expression is subject to modification by the environment; therefore, genotypic expression of the cultivaris environmentally dependent (Rao *et al.,* 2011). Thus, it is important to know if environmental differences have any effects on cashew genotypes, since such differences have already been observed in other tree crops (Omolaja *et al*., 2009; Omonona and Akintude, 2009; Oyekale *et al*., 2009).To this end, the present study aims to compare the behavior of different cashew genotypes in the context of Benin climate which is characterized by its irregular rainfall during the growth cycle (sometimes in abundance, and other times scanty, leading to marked water deficits) and heterogeneous soils.

MATERIAL AND METHODS

Study Area

This study was carried out at two cashew producing areas in Benin namely the Central and the North-Western zones. In the Centre, data were collected at Savè and Glazoué districts, while in the North-West they were collected in the district of Djougou (Figure 1). The villages of Adourékoman located at latitude 7°91'58"N and longitude 27°30"E in the district of Glazoué and Founga located at 09°40'50.0''N and longitude 001°35'42.5''E in the district of Djougou were considered based on their proximity to the meteorological stations to carried out agronomic experiment. Glazoué, one of the districts in the Department of *Collines* were selected from the areas of high production (Bello *et al.,* 2017). Glazouéis considered as a transition zone (between South and North) of 16,900 km² extending after the plateau of Abomey and Kétou until the 9th parallel north (Balogoun *et al.,* 2014). The district of Djougou in Donga department (North-western Area) was selected as area of medium production. The Northwestern parts of Benin are essentially of a mountain climate with slight variations from one locality to another. These soils are of fine clay-sandy texture. Lateritic and hydromorphic soils were also observed in these areas (INRAB, 1995).

Data Collection Methods

The study consisted in monitoring the phenology and productivity of cashew trees during four consecutive cropping seasons (2013-2014; 2014-2015; 2016-2016 and 2016-2017) in the villages of Adourékoman, and Founga. The cashew trees were identified based on a forest inventory carried out from June to July 2013 (Chabi Sika *et al.,* 2015). These four cashew genotype were selected according to their agro-morphological (Table 1) which were identified in Benin (Chabi Sika *et al.,* 2015). A total of 36 trees were used in an experimental design laid at randomized complete block in each site for data collection.

The plant phenology parameters measured were: days to the emergence of the flowers, days to apples and nuts formation, days to flowering and fruiting, number of male flowers per panicle, number of hermaphrodite flowers per panicle, number of abnormal flowers per panicle and total number of flowers per panicle. Five panicles bearing flower buds according to the four cardinal points (a total of 20 panicles were selected per tree) were selected for the counting of flowers. Figure 4.2 illustrates the different types of flowers observed on the panicle. The average rate of the different flowers types was determined per tree. Yield and yield components measured were: number of apples and nuts per tree,

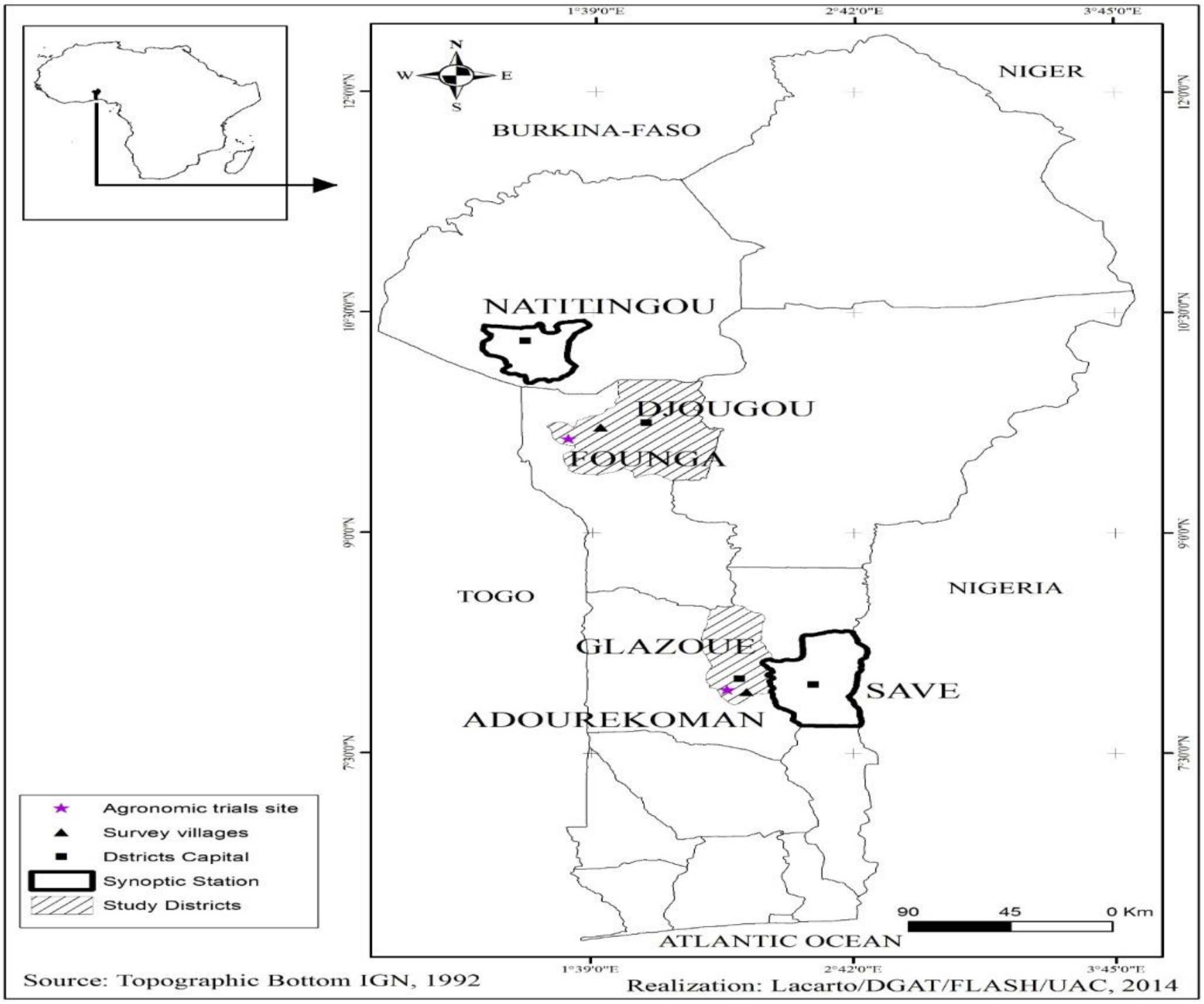

Figure 1: Geographical localization of the study area

Table 1: Characteristics of the four genotypes of cashew tree identified

Genotype	Cashew nuts and apples shape and colour		
	Apples Colour	**Apples shapes**	**Nuts shape**
M1Y	Yellow	Very large and long apples with round base and round apex.	Very large nuts with oblong shape and round apex.
M1R	Red	Very large and long apples with round base and round apex.	Very large nuts with oblong shape and round apex.
M2Y	Yellow	Small apples	Small nuts having kidney form with round base
M2R	Red	Small apples	Small nuts having kidney form with round base

weight of apples and nuts per tree, length and width of apples and nuts per tree. The total yield per tree was the sum total of nut collected and weighed throughout the period of harvest. The apple weight / nut weight ratio per tree was calculated from 10 fruits selected at random to determine the apples weight from the nuts weight (Balogoun *et al.,* 2016).

Statistical Analysis

The phenotypic and agronomic data obtained from the four years' experiments (2013-2014, 2014-2015, 2015-2016 and 2016-2017) and the two locations were subjected to analysis of variance (ANOVA), additive main effects and multiplicative interaction (AMMI), heritability (calculated according to Singh & Ceccarelli, (1996)), stability and Pearson correlation coefficient using ARiS software. AMMI was used in order to determine the effect of genotype x environment interaction on agronomic parameters. Similar, analysis of variance using the proc mixed procedure in Statistical Analysis System (SAS v 9.2) was performed to determine the significance of the main effects of genotype, environment, and genotype x environment according to Littell*et al.* (2002).

The statistical model was as follows; Yijk = µ + Gi+ Ej+ GEij+ Bjk+ εijk

Where by µ is the mean, Gi is the effect of the ith genotype, Ej is the effect of the jth environment, Geij is the interaction of the ith genotype with the jth environment, Bjk is the effect of the kth replication in the jth environment, and εijk is the random error

The following formula was used to compute the heritability:

$$h^2 = \frac{V_G}{V_G + V_E + V_{GE}}$$

RESULTS

General conditions of the study area

The weather conditions during the cropping season in the Centre and North East were presented in Table 2. In the North East, rainfall distribution and its amount were recorded throughout the growing season and were relatively high compared to the Central site. At Djougou District, the maximum monthly rainfall was 330 mm during the four years while the no rainfall was recorded in November, December, January and February. In 2016, the amount of rainfall was 1045.10 mm. the mean of maximum temperature was 31.20^{o}C while the minimum temperature was 21.43°C. In the Centre, the temperature varied between 21.2°C and 32.5°C. The maximum monthly rainfall was 280.22 mm while minimum was 0 mm in January and February 2016.

Table 2: Description of the agro-climatic condition of the study sites

				Temperature	
Site	**Climate**	**Soil**	**Rain fall (mm)**	**Min**	**Max**
Centre (Glazoué)	Transition	Ferric and Plintic Luvisols (FAO 2006)	900 to 1100 mm	21.2°C	32.5°C
North-west (Djougou)	Sudano-guinean	Tropical ferruginous soils	1100 to 1300 mm	25.29°C	30.76°C

Combined ANOVA for the yield components across the two environments

Table 3 presents the analysis of variance for the studied variables at each location and combined locations. No significant difference (P > 0.05) were found among the genotypes for the most characters studied at the two locations. Within the same environment there was no significant difference (P > 0.05) among the genotypes. Genotypes x environment interaction also did not showed significant (P>0.05) effects for the variables. The apple circumference was the only character revealing significant (P<0.05) effect for G x E interaction. The results from variance analysis of the phenology and reproductive data showed a significant influence (P < 0.001) of the environment on cashew parameters recorded. The coefficients of variation for the parameters studied vary between 6.85 % and 40.69% at the Centre and 8.13 % and 62.83% in the North-west (Table 3). With the combined analysis, coefficients of variation for parameters varied between 7.52% and 50.74%.

Relationship between agronomic traits

The combined analysis among cashew parameters is presented in Table 4. There were negative correlation between days to complete flower appearance, number of male flower per panicle, number of hermaphrodite flower per panicle, nut length, and nut weight, and positive correlation with days to nut emergence, number of abnormal flower per panicle, and apple cashew length. The highest significant correlation coefficient (r = 0.87; P < 0.001) was obtained between nut and apple weight. Same result was observed between the days to nut set and days to apple set. Positive correlation coefficient were recorded between days to apple emergence, number of male flower per panicle, number of abnormal flower per panicle, number of hermaphrodite flower per panicle, nut circumference, nut weight, apple length, apple circumference, and apple weight. A negative correlation coefficient was recorded for nut length (Table 4). The relationship between nuts circumference was positive with nut weight, apple length, apple circumference, and apple weight. Apple length and apple circumference was positively significant (r=0.513; P< 0.001). Nut and apple circumference were also positively and highly significant (r = 0.616; P< 0.001). There were negative and high significant correlation between the number of male flower per panicle and nut circumference (r = -0.367; P < 0.001), days to apple emergence and nut length (r = -0.366; P< 0.001).

Table 3: Result of the analysis of variance and combined analysis for the studied parameters at the Centre and North-west of Benin

		Phenological parameters							**Cashew Yield parameters**					
		Number of days after the setting of the first floral buds of the setting of plant organs				Number of flower types			Nut			Apples		
Locations	Parameters	First flowers	Completed appearance of flowers	Cashew nut	Apple	Male	Abnormal	Hermaphrodite	Length	Circumference	Weight	Length	Circumfe-rence	Weight
Centre	f-values	1.22ns	0.29 ns	0.64ns	0.81ns	0.49ns	0.80ns	0.24ns	2.38ns	0.76ns	0.15ns	0.66ns	0.95ns	0.66ns
	Coef. of variation (%)	16.74	13.41	12.61	10.83	6.61	40.69	48.25	8.20	6.85	19.88	16.49	10.44	10.44
North-West	f-values	0.23ns	0.47 ns	0.21ns	0.05ns	2.53ns	0.21ns	0.26ns	0.50ns	1.17ns	0.56ns	1.12ns	2.61ns	0.74ns
	Coef. of variation (%)	32.16	19.54	10.13	9.51	8.13	62.83	44.28	20.25	12.29	24.94	29.24	16.54	30.56
Combined analysis	f-values Environment	11.40***	39.62***	24.14***	22.39***	8.54**	49.53***	15.18***	72.00**	0.42ns	92.41***	1.28ns	16.45***	68.20***
	f-value genotype	2.08ns	1.35ns	0.27ns	0.13ns	4.01**	0.56ns	1.05ns	0.82ns	0.82ns	0.82ns	0.82ns	0.82ns	0.82ns
	f-values G x E	0.36 ns	0.52 ns	0.24ns	0.52 ns	0.98 ns	1.25ns	1.02ns	0.67ns	1.24ns	0.98ns	1.18ns	2.92*	0.91 ns
	Coef. of variation (%)	25.40	16.78	11.62	10.30	7.52	50.74	46.82	16.37	9.94	36.09	23.75	13.78	39.59

ns : P >0.05 ; ** : P<0.01 ; *** : P < 0.001.Coef = coefficient, ns= not significance

Table 4: Combined analysis and Pearson correlation coefficients of the 15 phenology and reproductive characters

		Period of plant organ set				**Number of flower types**			**Nut**			**Apple**		
		First flowers	Completed appearance of flowers	Cashew nut	Apple	Male	Abnormal	Herma-phrodite	Length	Circum-ference	Weight	Length	Circum-ference	Weight
Period of plant organ set	First flowers	1												
	Completed appearance of flowers	0.435**	1											
	Cashew nut	0.144*	0.173**	1										
	Apple	0.261***	0.401***	0.716***	1									
Number of flower types	Male	-0.153ns	-0.024ns	0.109ns	0.098ns	1								
	Abnormal	0.237***	0.491***	0.108ns	0.235***	-0.033	1							
	hermaphrodite	0.177**	-0.175**	0.271***	0.216***	-0.054	0.056ns	1						
Nut	Length	-0.219***	-0.138*	-0.315***	-0.37***	0.022ns	-0.159**	-0.372***	1					
	Circumference	0.155*	0.175**	-0.008ns	0.091ns	-0.367***	0.083ns	-0.145*	0.439***	1				
	Weight	0.104ns	-0.043ns	0.061ns	0.18**	-0.011ns	-0.134*	0.256***	-0.025ns	0.051ns	1			
Apples	Length	0.314***	0.461***	-0.12*	0.088ns	-0.097ns	0.201**	-0.177**	0.294***	0.347***	-0.05ns	1		
	Circumference	0.302***	0.288***	0.089ns	0.27ns	-0.287***	0.174**	0.084ns	0.091ns	0.513***	0.084ns	0.616***	1	
	Weight	0.141*	0.065ns	0.006ns	0.135*	-0.036	-0.095	0.207***	-0.053ns	0.05ns	0.875***	0.11ns	0.164**	1

ns : not significant P>0.05 ; * : P < 0.05 ; ** : P<0.01 ; *** : P < 0.001

Additive Main Effect and Multiplicative Interaction (AMMI) Analysis

The AMMI analysis for the 13 characters is presented in Table 5. The AMMI analysis for environment showed significant differences for all of the phenology and reproductive variables. Only the circumference of apple presented high significant difference (P<0.01) for genotype x environment Interactions (G x E I). No significant difference (P>0.05) were observed amongst the other traits though slight differences (probability) were recorded as shown in Table 5.

Effect of environment

As far as the locations are concerned, the results indicated that the cashew trees in the North-west showed better behavior than those found in the Centre. But, the plants from the Central parts of the country performed better in terms of apple length, apple circumference, nut circumference (Table 5) than those from North-west but not significantly different (P>0.05) except the apple circumference. We observed that the number of days to the first flower setting were high with the plants from the Centre.

Behavior of genotypes across environment

The performance of the genotypes in each environment was ranked by ecovalence (Wi) analysis (Tables 6). Genotypes response in the tested environment was not significant as indicated by G x E interaction. Differences were found in rankings of the plants at the two studied sites for all variables (Table 6). For the number of hermaphrodite flowers, the genotype with small fruit and yellow colour (M2Y) had the highest number of flowers in the North-west and genotype with the big fruit and red colour (M1R), had the lowest number of flowers in the Centre. Considering the nut weight, genotype with the small fruit and red colour, (M2R), had the highest weight in the North but the genotype with the big fruit and yellow colour, M1Y) combined high stability and moderate weight in the same location. The M1R with its moderate apple weight, showed the best stability for this parameter. In the North-west area, the apple weight was better than the apple weight in the Centre.M1Rcombined the best stability in terms of number of days to first flowering and better number of days to first flowering in the North than the Centre of Benin. In the North, all of the genotypes had nut weight greater than those of the Centre. The lowest nut weight was registered by genotype M1Y in the Centre. It was interesting to note that all of the genotypes in the North had nut weight greater than 5.00 kg (Table 5.6). The highest nut weight was recorded with genotype M2R (Table 6).

Table 5: Environment effects and AMMI on agronomic parameters

	Phenology Parameters							Yield Parameters					
Parameters	Period (number of days after the setting of the first floral buds) of the setting of plant organs				Number of flower types			Nut			Apples		
Location	First flowers	Completed appearance of flowers	Cashew nut	Apple	Male	Abnormal	hermaphrodite	Length	Circumference	Weight	Length	Circumference	Weight
Centre (mean)	15.49	64.78	51.11	74.95	60.81	9.01	13.39	3.69	6.51	1.67	7.91	15.45	12.64
North (mean)	14.48	50.87	39.74	63.10	68.72	5.51	16.47	4.16	6.45	5.83	7.68	14.62	54.63
General mean	14.98	57.82	45.42	69.02	64.76	7.26	14.93	3.92	6.48	3.75	7.79	15.03	33.63
Significance level for zone	ns	<0.001	<0.001	<0.001	<0.001	<0.001	<0.05	<0.001	>0.05	<0.001	>0.05	<0.001	<0.001
Significance level for G x E AMMI	0.60ns	0.99ns	0.67ns	0.48ns	0.26ns	0.72ns	0.99ns	0.65ns	0.30ns	0.50ns	0.62ns	0.01*	0.54ns

ns = not significant; * Significant at P < 0.05

Table 6: Ranking and mean performance of agronomic parameters from cashew plants (phenology parameters)

		Period (number of days after the appearance of the first floral buds) of the emergence of plant organs								Number of flower types					
Environment	**Rank**	**First flowers**		**Completed appearance of flowers**		**Cashew nut**		**Apple**		**Male**		**Abnormal**		**hermaphrodite**	
Centre		Genotype	Mean	Genotype	Mean	Genotype	Mean	Genotype	Mean	Genotype	Mean	Genotype	Mean	Genotype	Mean
	1st	M2R	17.03	M1R	69.77	M2R	55.50	M1Y	79.60	M1Y	63.47	M1R	9.50	M2R	13.61
	2 nd	M1R	16.14	M2Y	65.11	M1Y	51.12	M2R	78.62	M1R	60.81	M1Y	9.43	M2Y	13.47
	3 rd	M2Y	14.64	M1Y	63.80	M2Y	48.94	M2Y	72.25	M2R	60.10	M2R	9.10	M1Y	13.46
	4 th	M1Y	14.16	M2R	60.44	M1R	48.88	M1R	69.32	M2Y	58.87	M2Y	8.01	M1R	12.98
North-west	1st	M1Y	14.89	M1R	54.30	M1R	40.22	M1R	64.58	M1R	72.35	M1R	5.58	M2Y	17.30
	2 nd	M1R	14.75	M2Y	52.22	M1Y	40.17	M1Y	63.78	M1Y	71.63	M2Y	5.82	M2R	16.70
	3 rd	M2Y	14.33	M1Y	49.00	M2Y	39.80	M2Y	62.36	M2Y	70.94	M1Y	5.75	M1Y	16.18
	4 th	M2R	13.94	M2R	47.97	M2R	38.78	M2R	61.69	M2R	59.95	M2R	4.88	M1R	15.71

M1Y: genotype with big fruit and yellow colour; M1R: genotype with big fruit and red colour; M2Y; genotype with small fruit and yellow colour; M2R: genotype with small fruit and red colour

Table 6 continued: Ranking and mean performance of agronomic parameters from cashew plants (Yield parameters)

		Nut						Apples					
Environment	**Rank**	**Length**		**Circumference**		**Weight**		**Length**		**Circumference**		**Weight**	
Centre		Genotype	Mean	Genotype	Mean	Genotype	Mean	Genotype	Mean	Genotype	Mean	Genotype	Mean
	1st	M2Y	3.71	M2Y	6.60	M2R	1.84	M1Y	8.11	M2Y	15.70	M1R	14.97
	2 nd	M1R	3.69	M1R	6.52	M1R	1.73	M2Y	8.00	M2R	15.58	M1Y	14.15
	3 rd	M1Y	3.65	M1Y	6.47	M2Y	1.59	M2R	7.83	M1Y	15.42	M2R	10.88
	4 th	M2R	3.57	M2R	6.44	M1Y	1.53	M1R	7.70	M1R	15.12	M2Y	10.57
North-West	1st	M1Y	4.29	M1Y	6.66	M2R	7.01	M1Y	8.26	M1Y	15.47	M2R	62.15
	2 nd	M2Y	4.18	M1R	6.45	M1Y	5.84	M1R	7.64	M2R	14.72	M1Y	61.13
	3 rd	M2R	4.09	M2Y	6.36	M1R	5.43	M2R	7.48	M1R	14.28	M1R	53.03
	4 th	M1R	4.07	M2R	6.35	M2Y	5.06	M2Y	7.36	M2Y	114.00	M2Y	42.17

M1Y: genotype with big fruit and yellow colour; M1R: genotype with big fruit and red colour; M2Y; genotype with small fruit and yellow colour; M2R: genotype with small fruit and red colour.

Heritability of agronomic parameters in the Centre and North-west

The heritability was zero for most of the characters studied (Table 7). The nut weight was the most heritable character in the North (61.3%) and nut circumference was the most heritable character at the Centre (38.3%). The apple weight and nut circumference in both area Centre and North were heritable but poorly as they recorded 1.6 and 0.8, respectively. The heritability for phenology parameters were zero suggesting that selection in cashew breeding programme will be more effective for the reproductive values (which is of paramount importance for cashew producers and breeders) than selection for phenology parameters.

Stability of agronomic parameters

Table 8 revealed that, there were variations in stability of the plant agronomic traits as indicated by the results obtained where most of them were stable for one or more traits but instability was also shown in other traits. The most stable genotype for number of hermaphrodite flowers was M2R (tree with small fruit and red colour) (Table 8). As far as the apple length is concerned, we observed that genotype (genotype with big fruit and yellow colour) (M1Y) had almost the same length in the two locations and combined a better apple length and a good stability (Table 8) for nut weight. The agronomic trait is considered stable once the lowest Wi-eco-valence is recorded. The stability analysis of those parameters revealed that, the genotype with big fruit and red colour (M1R) was more stable across the locations as they recorded low Wi values for most of the characters. These characters were: period of flowers set, number of abnormal flowers per panicle, length and circumference of cashew nut, circumference and weight of apple. Other genotypes were not stables particularly genotype with small fruit and yellow colour (M2Y).

Table 7: Heritability of agronomic parameters in the Centre and North

		Centre	North-West
	Parameters	**H %**	**H %**
Period (number of days after the setting of the first floral buds) of the setting of plant organs	First flowers	-	-
	Completed appearance of flowers	-	-
	Cashew nut	-	-
	Apple	-	-
Number of flower types	Male	-	11.7
	Abnormal		-
	hermaphrodite	-	-
Nut	Length	-	-
	Circumference	38.3	0.8
	Weight	-	61.3
Apples	Length	-	-
	Circumference	-	-
	Weight	1.6	28.4

Table 8: Ranking and stability of genotypes in environment based on AMMI analysis (Phenology parameters)

	Period (number of days after the setting of the first floral buds) of the setting of plant organs								**Number of flower types**					
Rank	**First flowers**		**Completed appearance of flowers**		**First flowers**		**Completed appearance of flowers**		**Male**		**Abnormal**		**hermaphrodite**	
	Genotype	**G x E**	**Genotype**	**G x E**	**Genotype**	**G x E**	**Genotype**	**G x E**	**Genotype**	**G x E**	**Genotype**	**G x E**	**Genotype**	**G x E**
1st	M1R	0.070	M1Y	0.400	M1Y	0.086	M2Y	1.915	M1Y	0.086	M1R	0.015	M2R	0.000
2 nd	M2Y	0.251	M2Y	0.517	M2Y	2.485	M1Y	7.906	M2Y	2.485	M1Y	0.60	M1R	0.064
3 rd	MIY	1.520	M2R	1.027	M1R	3.663	M2R	12.925	M1R	3.663	M2R	0.263	MIY	0.075
4 th	M2R	2.158	M1R	1.214	M2R	14.315	M1R	25.230	M2R	14.315	M2Y	0.779	M2Y	0.273

Table 8 continued: Ranking and stability of genotypes in environment based on AMMI analysis (Yield and yield component parameters)

	Nut						**Apple**					
Rank	**Length**		**Circumference**		**Weight**		**Length**		**Circumference**		**Weight**	
	Genotype	**G x E**	**Genotype**	**G x E**	**Genotype**	**G x E**	**Genotype**	**G x E**	**Genotype**	**G x E**	**Genotype**	**G x E**
1st	M1R	0.000	M1R	0.000	M1Y	0.011	M2R	0.007	M1R	0.000	M1R	7.533
2 nd	M2Y	0.002	M2R	0.001	M1R	0.106	M1R	0.014	M2R	0.000	M1Y	12.454
3 rd	M1R	0.006	M2Y	0.017	M2Y	0.238	M1Y	0.071	M2Y	0.371	M2R	43.062
4 th	M2Y	0.012	M1Y	0.030	M2R	0.504	M2Y	0.088	M1Y	0.394	M2Y	53.971

M1Y: genotype with big fruit and yellow colour; M1R: genotype with big fruit and red colour; M2Y; genotype with small fruit and yellow colour; M2R: genotype with small fruit and red colour

DISCUSSION

Mutwali *et al.* (2016) stated that the selection and recommendation of cultivar under genotype x environment interaction play a vital role in plant breeding programme. They further stated that a breeder is most interested in choosing cultivars that perform better in different locations. Therefore, in the present study, the result of the AMMI analysis revealed significant difference in genotype by environment interaction ($P < 0.05$) for one character. For other parameters measured there were no significant difference for most of the agronomic variables indicating no differential genotypic responses across environment. The no significant G x E interaction indicated that there is consistency in performance of cashew genotypes across environments. Although, the fifteen parameters tested varied from one location to another. It is evident that there was wide variation in vegetative and reproductive parameters across the sites and the size of the variances due to the sites have shown the influence of environment on the performance of the genotypes. The significant effects of the environments indicated that the testing environments were statistically different in phenology and yield components, that is, the genotypes performed differently across locations. These results suggested that the genotypes performed differently at the various locations. The overall mean of weight nut in the North was much higher as compared to Centre, with 5.83 kg and 1.67 kg, respectively. These weight nuts were inferior to those found by Blaikie *et al*. (2002) and Madeni, (2016) with nut weight varying between 5.3 kg to 10.9 kg. Probably the low performance in the Centre may be attributed to the weather conditions that prevailed during the cropping season (Table 2), which did not favored the development of cashew and its high productivity. According to some authors, an analysis of the external environmental variables such as temperature, solar radiation, precipitation, and water holding capacity during various phenology phases helps to identify the potential causal factors of GEI (Signor *et al.,* 2001; Mutwali *et al.*, 2016).Most studies reported the environment effect on the growth, development and production of cashew trees and many others crop plants (Dhillion *et al.,* 2009; Anley *et al.,* 2013; Kumar *et al.,* 2014).

Climatic data showed that each environment (location) varies in rainfall (quantity and pattern), temperature, humidity, sunshine (spread and quantity), and harmattan (very dry and dusty wind), all of which could affect cashew flowering and fruiting differently (Balogoun *et al.,* 2016; Aliyu*et al.,* 2014). It was reported that wide genetic backgrounds (source of introduction, differential level of domestication and improvement) and open-pollinated (half-sib) source of cashew genotypes (Aliyu, 2012; Aliyu*et al.,* 2014) were responsible for high variability. According to Kaur *et al.*(2013) as cashew plant is cross-pollinated and heterozygous, considerable segregations have resulted in the cashew population. Furthermore, the wide phenotypic variability could be linked to the out-breeding nature of cashew (Desai *et al.,* 2010; Hamad *et al.,* 2013). It was proved that out-breeding crop systems are characterized by high genetic recombination (Charles worth and Wright, 2001; Glémin *et al.,* 2006) and its effect is to have a highly heterozygous population with diverse phenotypes (Aliyu *et al.,* 2014).

The variability found about genotypes in this work was low due certainly to the limited genotype number (four in total) used. It was observed that the nut weight and the apple weight varied within and between diverse ecologies (environments) and supposes that these characters could be improved through development of genotypes (varieties) with location-specific adaptation. Similar variability in nut weight was found by some authors (Madeni, 2016; Aliyu *et al.,* 2014) in their study. Among the two locations, the North-west had the best days to complete flower set (appearance). Warm climatic condition in the North favours good quality of flower production, male flower, hermaphrodite flower, and lower abnormal flower than that of the Centre (presenting cooler weather condition) location. Similar results were reported by Aliyu *et al.*(2014); Bello *et al.*(2016).However, each location has some comparative advantages. Climatic data (Bello *et al.,* 2016) showed that each environment (location) varies in rainfall (quantity and pattern), temperature, humidity, sunshine (spread and quantity), and harmattan (very dry and dusty wind), all of which could affect cashew flowering and fruiting differently.

The Genotype x Environment interaction data presented in the this research and those from many authors (Aliyu *et al.,* 2014; Madeni, 2016; Bello *et al.,* 2016) indicated that, an ideal cashew environment for optimal yield should include better soil fertility management, available soil moisture, optimal temperature, moderate relative humidity, moderate harmattan, moderate rainfall during the flowering and fruit development stage (Aliyu *et al.,* 2014; Balogoun *et al.,* 2016; Madeni, 2016) in order to avoid drop and drying of flowers.

The phenotypic correlations found in the present research were either negative or positive according to the parameters. The negative correlation did not showed evidence of strong linkage between nut weights which is an important criterion for farmers. But nut weight had a positive correlation with the number of hermaphrodite flower suggesting that a genotype which produces good number of hermaphrodite flower will have a good productivity. Although the relationship between nut size and total nut yield was positive and significant. The breeders must be careful in the use of this yield component characters as a selection criteria for cashew nut yield, due to the number-size trade-off complex (Aliyu and Awopetu, 2011). This result is similar to the result obtained by Chabi Sika *et al.* (2015) who obtained significant correlations (positive or negative) between variables such as the length and weight of the apple on one hand and the weight, length and width of the nut and inflorescence on the other hand in Benin.

The results also showed that the highest nut weight was recorded with genotype with small fruit and red colour (M2R) and the most stable genotype in the two environments was the genotype with big fruit and red colour (M1R). Ellis *et al.* (2004) compared variety trials in Australia, and reported that differences in cultivar ranking between yields were due to uneven deployment of cultivars in fields. They concluded that variety trials could not be enhanced to evaluate uneven deployment effects. However, Chabi Sika (2015), obtained no difference between red and yellow fruit trees. In South Africa (Redshaw, 2000) post-release variety trials have been used to recommend varieties to growers. Our study indicates that a systematic agronomic evaluation of released germplasm is valuable in determining relative cultivar performance and recommendation domains. The use of genotype with red fruit could be very useful to producers for large scale production of cashew in Benin.

CONCLUSION

The results indicated that cashew plants responded differentially to environment conditions. Some were stable across the two sites and according to the parameters suggesting that in the presence of G x E interaction the behavior of the individual genotype need to be taken into account at each site in order to facilitate the selection of those that perform well at both sites. Among the phenology and yield components characters of cashew, positive and significant correlations were observed. Results of this study are also of vital importance to cashew breeders who intend to improve and develop high yield and stability of cashew production. For others studies, more sites and more genotypes are highly recommended in order to have more information about environment and genotypes. From the results of the present research, it is recommended to undertake hybridization between genotype with small fruit and red colour (M2R) with another variety of cashew for the improvement of the productivity in North-western area of Benin.

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REFERENCES

Acikgoz E, Ustun A, Gul I, Anlarsal E, Tekeli AS, Nizam I, Avcioglu, R, Geren H, Cakmakci S, Aydinoglu B, Yucel C, Avci M, Acar Z, Ayan I, Uzun A, Bilgili U, Sincik M, Yavuz M(2009). Genotype x environment interaction and yield stability analysis for dry matter and seed yield in field pea (*Pisumsativum* L.). *Spanish J. Agric. Res.* 7(1): 96-106.

Aliyu OM (2012). Genetic diversity of the Nigerian cashew germplasm, 163-184. In: Genetic Diversity in Plants, eds. Mahmut Çalişkan. In Tech Publisher, *Croatia*, pp. 498.

Aliyu OM, Awopetu JA (2011). Variability study on nut size and number trade-off identify a threshold level for optimum yield in cashew (*Anacardium occidentale* L.). International Journal of Fruit Science, 11(4): 342-363.

Aliyu OM, Adeigbe OO, Lawal OO (2014). Phenotypic Stability Analysis of Yield Components in Cashew (*Anacardium occidentale* L.) Using Additive Main Effect and Multiplicative Interaction (AMMI) and GGE Biplot Analyses, *Plant Breed. Biotech.* 2(4):354~369

Anley W, Zeleke H, and Dessalegn Y (2013). Genotype x environment interaction of maize (*Zea mays* L.) across North Western Ethiopia. *Journal of Plant Breeding and Crop Science*, 5(9):171-181.

Balogoun I, Ahoton EL, Saïdou A, Bello DO, Amadji LG, Ahohuendo CB, Babatoundé S, Chougourou CD, Ahanchede A(2016). Effect of climatic factors on cashew (*Anacardium occidentale* L.) productivity in Benin. *Journal of Earth Science & Climate Change* (JESCC).,**7**(2): 329-338. DOI:10.4172/2157-7617.1000329.

Balogoun I, Saidou A, Ahoton EL, Amadji GL, Ahohuendo CB, Adebo IB, Babatoundé S, Chougourou D, Adoukonou SH, Ahanchédé A. 2014. Characterization of cashew's production systems in the main cropping zones of Benin. *Agron Afr* 26: 9-22.

Bello OD, Akponikpè PBI, Ahoton EL, Saidou A, Ezin AV, Kpadonou GE, Balogoun I, and Aho N (2016). Trend Analysis of Climate Change And Its Impacts On Cashew Nut Production (*Anacardium Occidentale* L.) In Benin. *Oct. Jour. Env. Res,* 4 (2), 181-197.

Bello OD, Ahoton LE, Saidou A, Akponikpè IPB, Ezin VA, Balogoun I, Aho N (2017). Climate change and cashew (*Anacardium occidentale* L.) productivity in Benin: perceptions, endogenous measures of adaptation. *Int. J. Biol. Chem. Sci.* 11(3): 924-946.

Blaikie S, O'Farrell P, Warren M, Wei X, Scott N, Sykes S, Chacko E(2002). Assessment and Selection of New Cashew Hybrids. Environmentally friendly paper, Canprint. Publication number 01/177. 29p.

ChabiSika BK 2(015). Caractérisation agro-morphologique, biochimique et génétique moléculaire des accessions d'anacardier cultivées au Bénin. Thèse de doctorat de l'Université d'Abomey-Calavi, Bénin.147p

ChabiSika K, Adoukonou-Sagbadja H, Ahoton LE, Adebo I, Adigoun FA, Saidou A, Ahanchede A, Kotchoni SO, Baba-Moussa L(2015). Morphological characterization and agronomic performances of cashew (*Anacardium occidentale* L.) accessions from Benin, *Journal of Agricultural and Crop Research*, **3**(2): 27-40.

Charles worth D, Wright SI(2001). Breeding systems and genome evolution. Current Opinion in Genetics & Development 11: 685-690.

Desai AR, Mokashi AN, Korikanthimath VS, Fakrudin B, Patil RV, Hegde RV, Gadag RN(2010). Comparative analysis of morphometric and molecular diversity in cashew (*Anacardium occidentale* L.) genotypes. *Indian Journal of Plant Genetic Resources*, 23: 104-109.

Dhillion SK, Singh G, Gill BS, and Singh P(2009). Stability analysis for grain yield and its components in soybean (*Glycine max.* L. Merrill). *Crop Improvement*, 36(1): 55-58.

Ellis RN, Basford KE, Leslie JK, Hogarth DM, Cooper M(2004). A methodology for analysis of sugarcane productivity trends. 2. Comparing variety trials with commercial productivity. *Aust. J. Agric. Res.* 55, 109–116.

Gauch HG (2013). A simple protocol for AMMI. Analysis of yield trials. *Journal of Agricultural Sciences* 143:449-462.

Gauch HG, Rodrigues PC, Munkvod JD, Heffner EL, Sorrels M(2011). Two new strategies for detecting und understanding QTL x Environment interactions. *Crop Science* 51: 96-113.

Glémin S, Bazin E, Charles worth D (2006). Impact of mating systems on patterns of sequence polymorphism in flowering plants. *Proc. R. Soc. B*, 273: 3011-3019.

Hamad SAA, Ahmed AHR, and Mohamed AIA(2013). Effect of production location and addition of guar gum on the quality of a Sudanese wheat cultivar for bread making. *Int. J. Innov. Appl. Stud.* 7:317–328.

INRAB(1995). Fiches techniques sur les sols et les essences forestières. INRAB Cotonou. Bénin. édition 1995, p. 68.

Kaur A, Singh N, Ahlawat AK, Kaur S, Singh AM, Chauhan H(2013). Diversity in grain, flour, dough and gluten properties amongst Indian wheat cultivars varying in high molecular weight subunits (HMW-GS). *Food Res. Inter*. 53:63–72.

Kumar R, Singode A, Chikkappa GK, Mukri G, Dubey RB, Komboj MC, Singh HC, Olakh1 DS, Ahmad B, Krishna M, Zaidi PH, Debnath MK, Seetharama K, Yadav OP(2014). Assessment of genotype × environment interactions for grain yield in maize hybrids in rainfed environments. SABRAO. *Journal of Breeding and Genetics* 46 (2) 284-292.

Littell RC, Stroup WW, Freund RJ(2002). SAS software for Linear Models, 4th ed. SAS Institute Inc., Cary, NC, 466 pp.

Madeni JFN (2016). Genotype x environment interaction on selected cashew (*Anacardium occidentale* L.) hybrids in Tanzania. Master of Science in Crop Science of Sokoine University of Agriculture Morogoro, Tanzanian, 116p.

Mutwali NIA, Mustafa IA, Yasir SA, Gorafi SAY, and Ahmed IAM(2016). Effect of environment and genotypes on the physicochemical quality of the grains of newly developed wheat inbred lines. *Food Sci Nutr*, 4(4): 508–520.

Omolaja SS, Aikpokpodion P, Adedeji S, Vwioko DE(2009). Rainfall and temperature effects on flowering and pollen productions in cocoa. African Crop Science Journal, 17 (1): 41-48.

Omonona BT, Akintunde OK(2009). Rainfall effects on water use and yield of cocoa in Nigeria. Continental J. Agricultural Economics 3: 52-60.

Oyekale AS, Bolaji MB, & Olowa OW(2009). Effects of climate change on crop production and vulnerability in Nigeria. *Agricultural Journals,* 4, 77–85.

Rao KPC, Ndegwa WG, Kizito K, Oyoo A(2011). Climate variability and change: Farmer perceptions and understanding of intra-seasonal variability in rainfall and associated risk in semi-arid Kenya. *Experimental Agriculture* 47: 267–291.

Redshaw K (2000). Agronomic evaluation of released varieties in South Africa. Intl. Soc. Sugar Cane Technol. Agron. Workshop, 2–6 December 2000. FL, USA. Online abstract. http://issct.int-net.mu/agroabs.htm#4.

Singh M, & Ceccarelli S(1996). Estimation of heritability of crop traits from variety trial data. Aleppo: ICARDA. Technical Manual 21.

Signor CEL, Dousse S, Lorgeou J, Denis JB, Bonhomme R, Carolo P, Charcosset A(2001). Interpretation of genotype environment interactions for early maize hybrids over12 years. *Crop Sci* 41:663-669.

Smith AB, Cullis BR, Thompson R(2005). The analysis of crop cultivar breeding and evaluation trials: an overview of current mixed model approaches. *Journal of Agricultural Sciences* 143:449-462.

Yabi I, Yabi BF, Dadegnon S. (2013). Diversité des espèces végétales au sein des agroforêts à base d'anacardier dans la Commune de Savalou au Benin. *International Journal of Biological and Chemical Science*, **7**(2): 696 - 706. http://dx.doi.org/10.4314/ijbcs.v7i2.10.

Yan W, and Hunt LA(2002). Interpretation of Genotype x Environment Interaction for Winter Wheat Yield in Ontario [http://crop.scijournals.org/cgi/content/full/41/1/19] assess the 12/06/2017.