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Research Article

Yield Performance and Stability of Some Introduced Castor Hybrids in Nigerian Ecology

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Abstract

Castor (*Ricinus communis* L.) is an industrial oil crop that is widely recognized as an ideal crop for tropical and subtropical regions. Nigeria has been identified as a country with high potential to meet her national castor oil need and provide surplus for export. This potential can be harnessed, only if adequate production technologies, such as improved varieties, are available to the farmers. In this research, three introduced castor hybrids (Code 11, Code 22 and Code 33) and two local checks (NCRICAS1 and NCRICAS2) were assessed for their yield performance and stability in Nigeria. The castor genotypes were evaluated in a replicated plots across six locations in the savanna ecologies of Nigeria. The results revealed significant differences for traits assessed among the genotypes. Average seed yield among the hybrids ranged between 596.58kg/ha and 1372.49kg/ha. Average seed yields of the checks ranged between 849.58kg/ha and 1239.63kg/ha. The hybrid Code 33 out yielded the two local checks at four locations (Badeggi, Benue, Kebbi and Sokoto) out of the six locations. The check 1 (Acc.036) recorded significant higher yield (1705.28kg/ha and 1648.15kg/ha) than the hybrid Code 33 (1573.91kg/ha and 867.58kg/ha) at Bacita and Bauchi locations. Besides recording comparable seed yield to the best hybrid (Code 33), the local check 1 (NCRICAS2) matured earlier than the hybrids evaluated. The GGE biplot view revealed good stability and responsiveness for both hybrid Code 33 (G5) and Acc.036 (G2). Based on performance *per se,* the hybrid Code 33 showed better adaptation to the ecology. However, further assessment on oil quantity and quality, and cost benefit analysis of the hybrid(s) in comparison to the local varieties is highly recommended.

Keywords: *Castor, GGE biplot, G × E interaction, stability, yield*

Introduction

Castor (*Ricinus communis* L.) is becoming regaining treasure oil crops with high economic value around the world (Gana, 2015; Alhaji *et al.*, 2019). Its production is economically needed in Nigeria to address the estimated consumption rate of more 300,000 tonnes per year in the country (RMRDC, 2009; Ibeagha and Onwualu, 2015; Salihu *et al.*, 2021). The major castor production limit in Nigeria remains the access to improved and suitable planting materials (Salihu *et al.*, 2021). Breeding efforts have been deployed to provide the farmers with improved and acceptable varieties across different ecologies of the country; however, this entails adequate assessment of the performance and stability of any intended variety in the ecologies.

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Estimation of yield performance and stability of crop products is of interest to plant breeders (Sarijaloo *et al*., 2021). Varietal introduction as well as other breeding procedures entails the assessment of performance *per se* and stability of the performance across target locations. This is to assess relative performance predictability and consistency of the introduced materials in new environment. The introduced individuals must have optimum performance and good stability for the trait of interest across target locations. Grain yield remains the most important measure of crop performance and is undoubtedly of utmost interest to plant scientists. Being a polygenic trait, yield measurement is influenced by a number of factors in the crop micro and macro environments (Comstock and Moll, 1963). Both predictable (also controllable) and unpredictable (uncontrollable) environmental factors are of importance in crop yield performance (Perkins and Jinks, 1968). No or low influence of uncontrollable factors is preferred as it signifies stability, while high level influence of controllable is agronomically preferred as it gives room for exploitation of improved environmental factors to obtain maximal performance (Perkins and Jinks, 1968). However, the influence of these factors is not exactly the same on the performance of two or more genotypes and also in all locations; resulting to changes in the performance of the genotypes from one location to the other. Different genotypes and crop types show different levels of plasticity to changes in environments (Pagi *et al.*, 2017).

The crop yield performance is dependent on the genotype, environments and the interaction between the two. Assessment of stability of the performance for economically important characters is always of interest to the plant breeder. Chaudhari *et al*. (2019) reported significant influence of environments while assessing stability of twenty-six castor genotypes under three environments. The knowledge of magnitude and the nature of interaction between genotype and environments has been identified as a guide for genotype stability (Chaudhari *et al*., 2019). Several authors have assessed the high magnitude of the interaction between genotype and environments in castor using various methods (Patel and Pathak, 2006; Patel *et al*., 2010; Patel *et al*., 2011; Dhedhi *et al.*, 2012; Patel *et al*., 2015).

Different useful statistical techniques to measure crop traits stability have developed by a number of scientists (Finlay and Wilkinson, 1963; Eberhart and Russell, 1966; Perkins and Jinks, 1968). Yan *et al*. (2000) proposed another methodology known as GGE-biplot for graphical display of GE interaction pattern of multi environment trial data with many advantages. Chaudhari *et al*. (2019) deployed the statistical techniques proposed by Eberhart and Russell (1966) to understand the G × E interaction and stability of different castor genotypes in Indian. Memon *et al.* (2023) deployed Additive Main Effect and Multiplicative Interaction (AMMI) model and Genotype × Genotype × Environment (GGE) biplot techniques to select elite genotypes of castor across western rain fed regions of India. In the present study, GGE-biplot analysis was employed to assess the yield performance and stability of some Indian Castor Hybrids in the savanna ecology of Nigeria.

Materials and Methods

The castor genetic materials used for the study include three hybrids (Code-11, Code-22 and Code-33) from Farm Tech Biogene Pvt. Ltd., India and two local checks (NCRICAS 1 and NCRICAS 2) from National Cereals Research Institute, Badeggi, Nigeria. The castor genotypes were evaluated during 2021 raining season at six locations across the savanna ecologies of Nigeria. The experimental sites, climatic information and the descriptions of their surrounding environment are presented in Table 1.

The experimental layout was Randomized Complete Block Design with a 5.4m x 6.0m plot replicated three times. Manual land clearing and ridging were done. Farm Yard Manure was incorporated on each plot at the rate of 8t/ha before ridging. Planting was done in early to mid-June 2021 when the rain was well established. Inter-rows spacing of 0.9m and intra-rows of 0.75m were adopted. Two (2) seeds were sown per hill at about 4 – 5cm depth. Planting was carried out manually in all locations. Provision was made for the filling of missing plant stand (*seedlings were raised at the time of planting in polythene pots and these were used for the supply* *after 7-10 days).* Fertilizer was applied at the rate of 60N: 30P: 30K (kg/ha). Fifty percent (50%) of N + Full P and K (30N: 30P: 30K) were applied as basal at 15 days after planting. The balance (50%) N was applied in two splits, one (25%) at 40-45 days after planting (DAP) and the second (25%) at 70-80 days after planting when the soil was wet. Two spray (7 days intervals) of insecticide (Magic force) was applied at 100ml in 15L of water at 7 - 10 days DAP to prevent insect attack. This was repeated at flowering (about 60 - 70 days DAP) at interval of 10 days after flowering. Fungicide (Binhomyl 50 WP) was applied at the rate of 40g in 15L of water for the control of fungi diseases. The fungicide was applied at one week after seedling emergence, one and two weeks after flowering initiation. The plots were hoe weeded at 2, 4 and 6 weeks after planting. When few (3-4) capsules in a spike were dried and the majority of other capsules had turned yellow or light brown, the spikes were harvested and dried in a water free environment.

Data were collected on days to flowering of primary raceme (DF), number of racemes per plant (RPP), days to primary raceme maturity (DM), height at maturity (HM) and seed yield (SY). The data were taken according Salihu *et al*. (2019). Data were subjected to analysis of variance. Stability analysis through Genotype, Genotype by Environment (GGE) Biplot was done following the procedure of Plant Breeding Tools (PBTools 1.3).

Results and Discussion

The analysis of variance revealing the magnitude of variations contributed by genotype, location and their interaction on five traits assessed among the five castor varieties are shown in the Table 2. There were significant effects of genotypes and locations on all the traits assessed. However, there was no significant interaction on all the traits except for the seed yield. The seed yields of the hybrids and the checks at individual location are presented in the Table 3. Individual location yields, for the genotypes assessed, ranged from 1282.11 kg/ha (Kebbi) to 674.07 kg/ha (Sokoto). The hybrid Code 33 out yielded the two local checks at four out of the six locations. The Check 1 (NCRICAS2) recorded significant higher yield (1705.28kg/ha and 1648.15kg/ha) than the hybrid Code 33 (1573.91kg/ha and 867.58kg/ha) at Bacita and Bauchi locations (Table 3). The hybrid Code 11 out yielded the two checks at Badeggi, Makurdi and Sokoto. The hybrid Code 22 recorded least yield among the hybrids and it only out yielded the Check 2 (NCRICAS1) at one location (Sokoto). The hybrid Code 11 recorded potential yield of 1509.98kg/ha at Makurdi. Potential yields of 1798.47 kg/ha and 1002.53 kg/ha were observed for Code 33 and Code 22 respectively at Sokoto (Table 3). Average seed yields and other traits of the entries across the locations are presented in the Table 4. The least days (93.59 days) to maturity was recorded in check 1 (NCRICAS1). Hybrid Code11 produced highest number of racemes per plant (14.19) among the entries. Hybrid Code22 was tallest of all entries with average height of 147.91 cm. The hybrid Code 33, Code 22 and Code 11 recorded average seed yields of 1372.49kg/ha, 596.58kg/ha and 1146.47kg/ha respectively (Table 4). The best hybrid (Code 33) recorded non-significantly different average yield to local Check 1; though, the hybrid (Code 33) showed 10.72% yield advantage over the local Check 1. Hybrid Code 11 and Code 33 recorded percentage yield advantage of 34.95% and 61.55% respectively over the local Check 2 (Table 4). Hybrid Code 22 recorded lower seed yield than the two checks. The observed range of means reported here is similar to those reported by Patel *et al.* (2010), Patel *et al.* (2011), Dhedhi *et al.* (2012), Patel *et al.* (2015) and Chaudhari *et al*. (2019). In a similar study in Nigeria, Abimiku *et al*. (2012) reported similar effects of genotypes and locations on yield and yield components in castor. Similar pattern of significant for traits was recorded in a study of 102 castor accessions in Ethiopia (Alemaw, 2016).

The results of GGE biplot analysis for entries are presented in Figure 1, 2 and 3. The first two principal components (PC1 and PC2) explained 93.1% of the total GGE variation, with PC1 and PC2 explaining 61.2% and 31.9%, respectively. The GGE biplot view revealed good stability and responsiveness for the hybrid Code 33 (G5) and Check 1 (G2) (Figure 1). Hybrid Code 33, Check 1 and Code 11 (G3) recorded higher yield than average genotypes mean (Figure 1). The Figure 2 presents What-Won-Where Biplot for the yield performance of the entries. Hybrid Code 33 performed best in location E2 (Badeggi), E4 (Kebbi), E5 (Makurdi) and E6 (Sokoto). The Check 1 performed best in location E1 (Bacita) and E3 (Bauchi) as showed in biplot. Assessing the similarity, representativeness and discriminating abilities of the six locations, the figure 3 shows that the locations are fitted into two groups; with Bacita (E1), Bauchi ((E3) and Kebbi (E4) in a group (Group A) and Badeggi (E2), Makurdi (E5) and Sokoto (E6) in another group (Group B). This showed that the locations within the same group showed similar environmental conditions during the trials. However, the longest projection for Bauchi (E3) in Group A and Badeggi (E2) in Group B showed that the two locations had the highest discriminating ability within each of the groups respectively. The representativeness of the locations is showed by their proximity to the Average Environment Axis (AEA); therefore, location E4 (Kebbi) in Group A and location 6 (Sokoto) in Group B showed the best representativeness for groups respectively. The implication of this is that the locations with high discriminating ability and best representativeness could be mostly considered in future evaluation especially when there is limited resource to work with. The findings reported here are similar to the reports of Tank (2000), Patel (2001), Solanki and Joshi (2003), Thakker *et al.* (2010), Patel *et al.* (2011), Dhedhi *et al.* (2012), Patel *et al.* (2015) and Chaudhari *et al*. (2019). Sakhare *et al.* (2018) reported a contribution 98% of the total GGE variation for the first two principal components (PC1 and PC2) in a GGE-biplot analysis of 10 castor genotypes. High contribution to variation within the PCA1 and PCA2, and two high yielding and stable castor genotypes were also reported by Salihu *et al.* (2021).

Conclusion

The study reported the potential of three introduced castor hybrids in savanna Agro-ecology of Nigeria. The hybrids and the local checks showed varying performances and stabilities across the six locations. The best yielding hybrid showed no significant performance than the best local check, though with hybrid recorded a considerable yield advantage over the check.

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Table 1: The experimental sites used and the descriptions of their surrounding environment

S/N	Sites	States	Coordinates	Mean Rainfall (mm)	Mean Temp	Previous cropping	Prevailing weeds	Agro-cology
1	NCRI Badeggi	Niger State	09.45° N, 06.07° E	1092.9	28.0 ^{0}C	Castor	*Paspalum scrobiculatum, Cryperus esculentus, Cynadon dectylon*	Southern Guinea Savanna
2	NCRI Station	Kebbi State	11.49° N, 04.23° E	800	31.0^{0}C	Castor	*Danelia oliveri; Impereta cylindrica*	Northern Guinea Savanna
3	University of Agriculture Makurdi	Benue State	07.46^o N, 08.48^o E	1250	37.8^{o}C	Cowpea	*Boerhavia diffusa L., Synederella nodifora, Spigella anthelima L.*	Southern Guinea Savanna
S4	NCRI Bacita,	Kwara State	09.07^o N, 04.96^o E	1517	26.5 ^{0}C	Castor	*Danelia oliveri; Impereta cylindrica; Cleomi viscose*	Southern Guinea Savanna
5	Kafin Madaki,	Bauchi State	10.41^o N, 09.45^0 E	909	35.0 ^{0}C	Ground nut	Grasses	Northern Guinea Savanna
6	Uthman Danfodio University Sokoto	Sokoto State	13.08^0 N, 5.13^0 E	587.25	27.3^{0}C	Milet	Grasses	Sudan Savanna

Table 2: Analysis of Variance on five agronomic data of three castor hybrids and two local checks in Savanna Agro-ecology of Nigeria

Traits	Sources of Variation	Degree of Freedom	Sum of Square	Mean Square	F-value	P-value
DF	Location (E)	5	9737.06	1947.41	21.74	0
	Block within Location	12	217.02	18.09	0.2	NS
	Genotypes (G)	4	4590.49	1147.62	12.81	0
	G × E	20	1856.73	92.84	1.04	NS
	Pooled Error	48	4300	89.58		
	Total	89	20701.31			
RPP	Location (E)	5	15663.39	3132.68	153.16	0

	Block within Location	12	245.44	20.45	1.18	NS
	Genotypes (G)	4	716.28	179.07	10.34	0
	G × E	20	545.5	27.28	1.57	NS
	Pooled Error	48	831.65	17.33		
	Total	89	18002.27			
DM	Location (E)	5	40114.83	8022.97	1493.09	0
	Block within Location	12	64.48	5.37	0.34	NS
	Genotypes (G)	4	5141.71	1285.43	81.72	0
	G × E	20	4503.38	225.17	1.03	NS
	Pooled Error	48	10497.07	218.69		
	Total	89	60321.47			
HM	Location (E)	5	1014103	202820.7	200.14	0
	Block within Location	12	12160.58	1013.38	1.55	NS
	Genotypes (G)	4	9376.72	2344.18	3.58	0.01
	G × E	20	20565.82	1028.29	1.57	NS
	Pooled Error	48	31446.72	655.14		
	Total	89	1087653			
SY	Location (E)	5	3831382	766276.5	38.99	0
	Block within Location	12	235864.7	19655.39	1.49	NS
	Genotypes (G)	4	7052044	1763011	133.61	0
	G × E	20	5241772	262088.6	19.86	0
	Pooled Error	48	633352.8	13194.85		
	Total	89	16994415			

Note: DF = Days to 50% Flowering, RPP = Racemes per Plant, DM – Days to Maturity, HM = Height at Maturity, SY = Seed Yield, NS = Not significant

Table 3: Mean Values for Seed Yield (Kg/ha) of Three FTB Castor Hybrids and Two Local Checks at Six Locations in Nigeria

GENOTYPES	BACITA	BADEGGI	BAUCHI	KEBBI	MAKURDI	SOKOTO
NCRICAS2 (Check 1)	1705.28	884.45	1648.15	1055.56	908.13	1234.51
NCRICAS1 (Check 2)	945.15	858.43	1138.88	314.81	896.09	920.50
Code11	1190.95	1464.04	592.60	666.67	1509.98	1454.57
Code22	843.57	486.42	350.93	185.19	710.85	1002.53
Code33	1573.91	1641.81	867.58	1148.15	1205.04	1798.47

Mean	1251.77	1067.03	919.63	674.07	1046.02	1282.11
LSD	108.45	252.1	150.81	270.42	321.79	211.00

Table 4: Combined Means for Five Important Agronomic Traits of Three FTB Castor Hybrid and Two Local Checks at Different Locations in Nigeria

GENOTYPE	DF	RPP	DM	HM (cm)	SY (Kg/ha)	% YA Over Check 1	% YA Over Check 2
NCRICAS2 (Check 1)	45.53	13.68	93.59	128.01	1239.63		
NCRICAS1 (Check 2)	66.95	7.66	111.11	124.05	849.58		
Code11	54.83	14.19	106.06	139.85	1146.47	-	34.95
Code22	64.33	7.65	116.83	147.91	596.58	-	-
Code33	53.72	9.31	107.06	135.35	1372.49	10.72	61.55

Note: DF = Days to 50% Flowering, RPP = Racemes per Plant, DM – Days to Maturity, HM = Height at Maturity, SY = Seed Yield, % YA = Percentage Yield Advantage

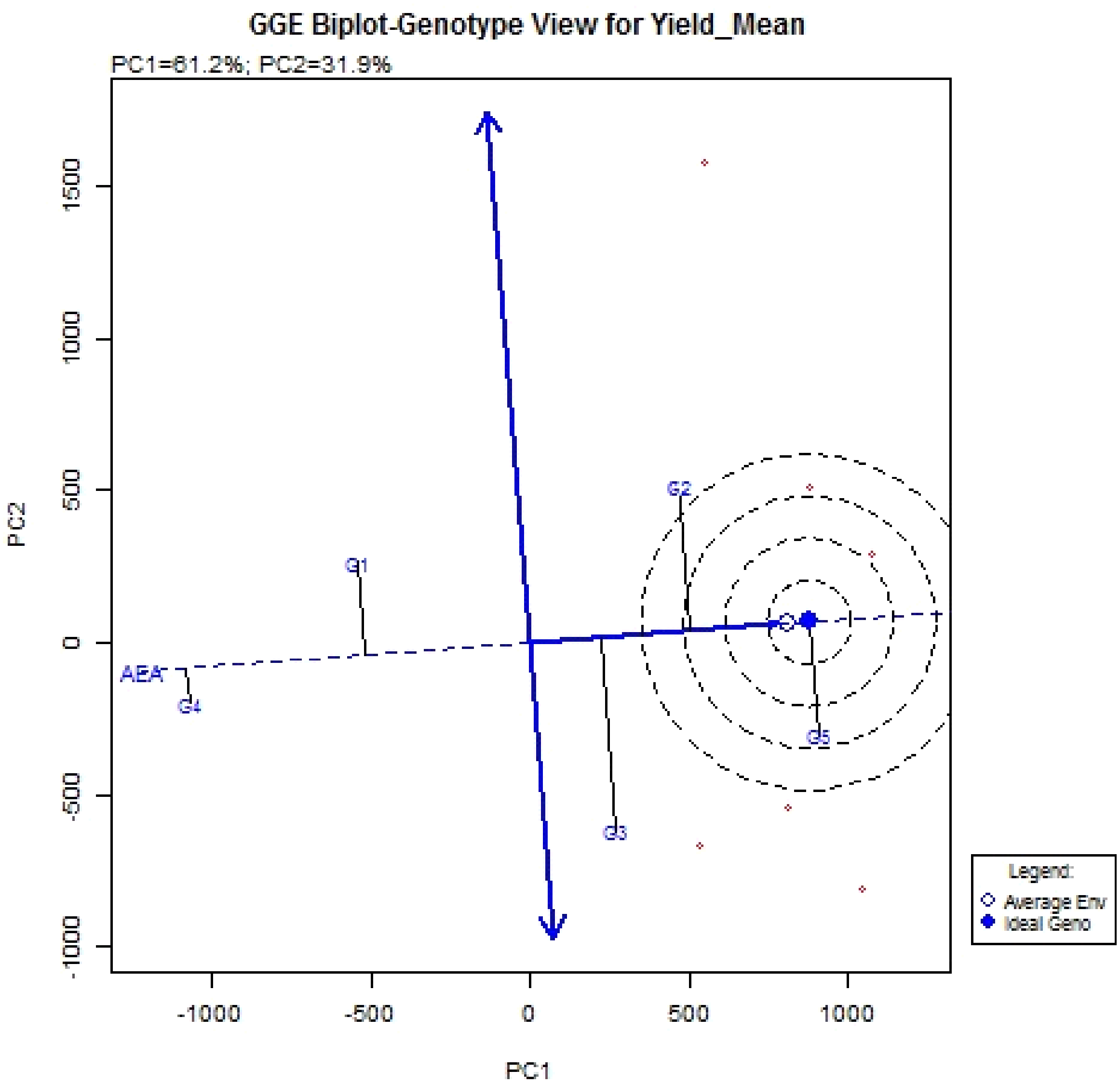

Figure 1: Mean performance and stability of three castor hybrids and two local checks in terms of grain yield as measured by principal components across different locations

Note: NCRICAS1 = G1, NCRICAS2 = G2, Code11 = G3, Code22 = G4, Code33 = G5

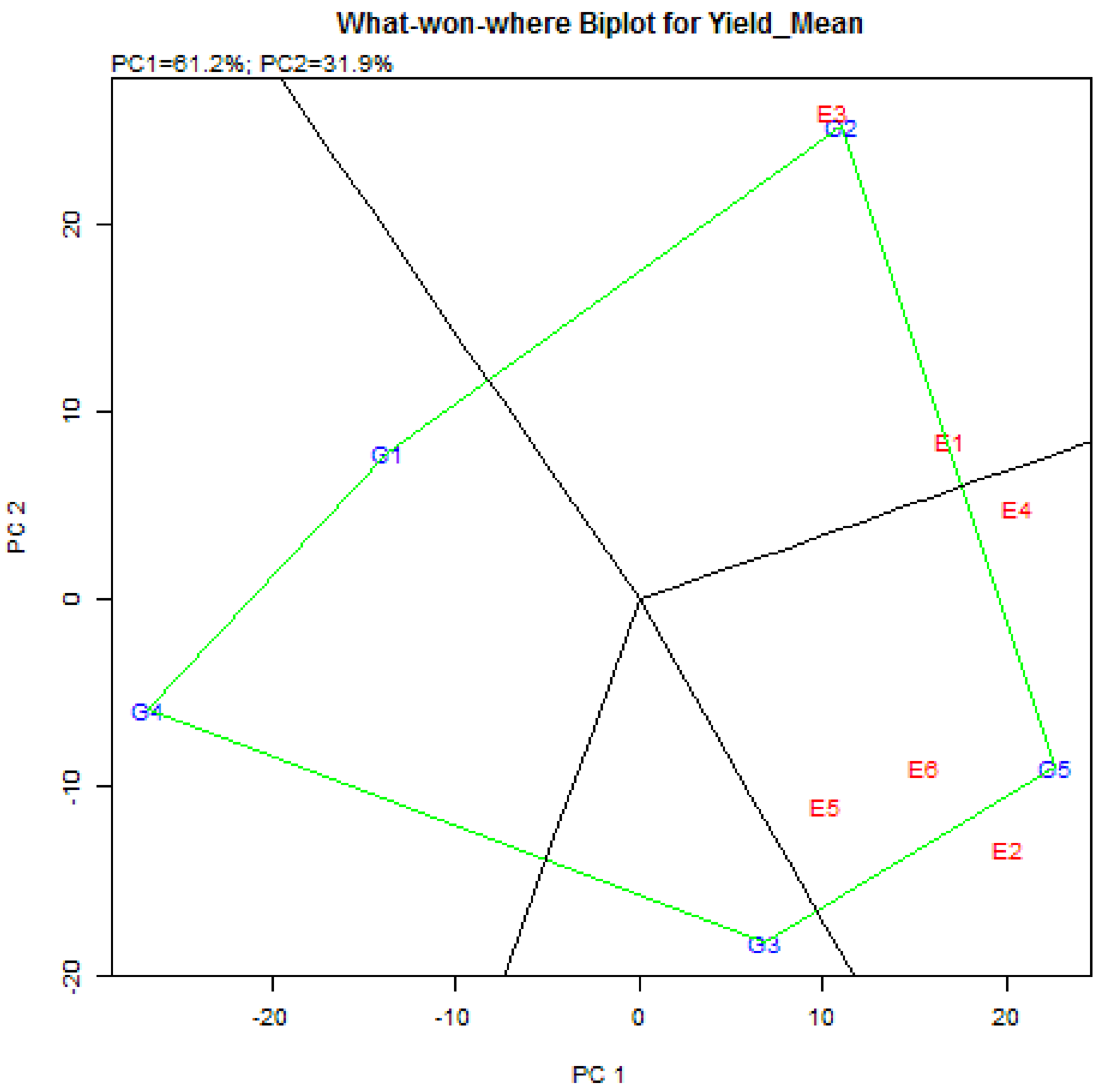

Figure 2: The which-won-where view of the GGE biplot showing which genotypes performed best in which environment

Note: NCRICAS1 = G1, NCRICAS2 = G2, Code11 = G3, Code22 = G4, Code33 = G5, BACITA = E1, BADEGGI = E2, BAUCHI = E3, KEBBI = E4, MAKURDI = E5, SOKOTO = E6

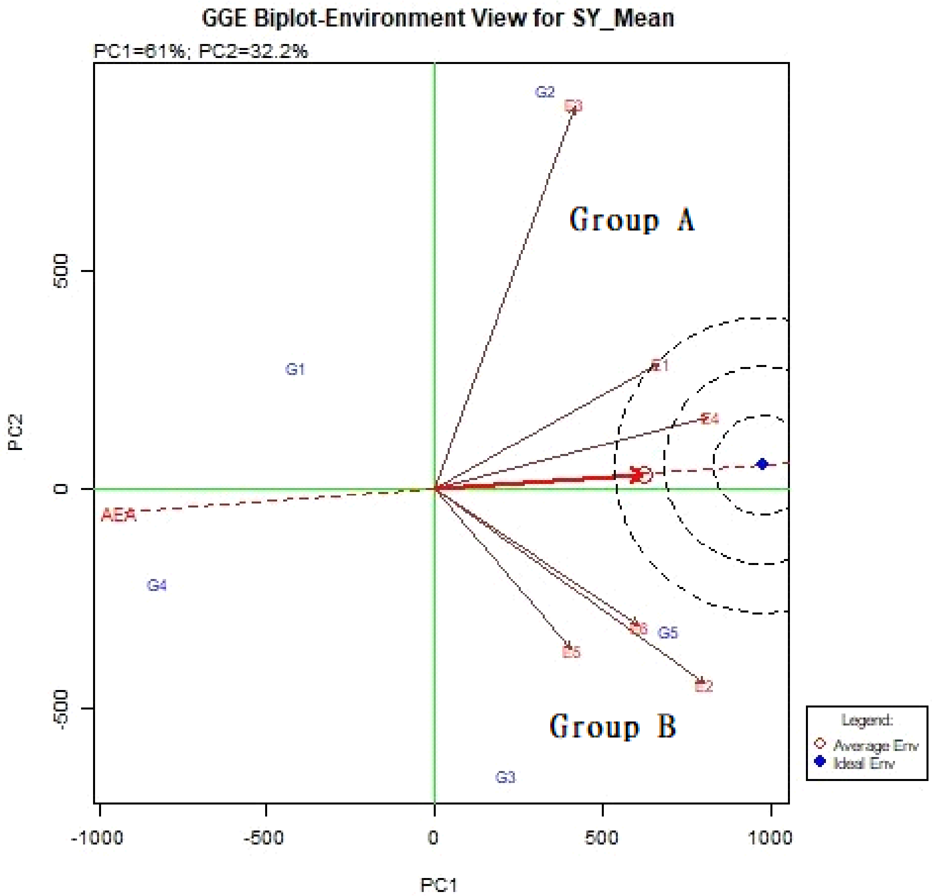

Figure 3: Similarity, Representativeness and Discriminating Ability of Six Locations on Castor Yield Performance in Savanna Agro-ecology of Nigeria

Note: *BACITA = E1, BADEGGI = E2, BAUCHI = E3, KEBBI = E4, MAKURDI = E5, SOKOTO = E6*