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AMMI Stability Studies of Cassava Clones for Arid and Semi-Arid Agro-Ecological Regions in Nigeria

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Abstract

Due to the increasing demand for cassava for food and raw materials for industries, it has become important to scale up production by providing farmers with suitable cassava varieties that are specifically bred for their ecological region. The study objective was to identify stable and well-adapted cassava genotypes suitable for arid and semi-arid environments in Nigeria. In this study, twenty cassava genotypes obtained through hybridization and then raised from true seeds, together with four checks were evaluated in four locations: Minjibri in Kano, Aliero in Kebbi, Otobi in Benue, and Umudike in Abia State. AMMI breeding value was used to study the mean performance and stability of the clones for important yield traits. The trial was set up in a randomized Complete Block Design (RCBD) with three replications in each location. Plot size of $20m^2$(4m x 5m dimension i.e. 4 rows by 5 plants) was used with a planting distance of 1 X 1m inter and intra row spacing giving a total plant population of 10,000 plants/ha. The combined analysis of variance shows that there were significant differences among the genotypes and locations for dry matter content (DMC), fresh root yield (FRY), dry root yield (DRY), harvest index (HI) and starch content at $P<0.001$. According to the results of the AMMI study, the best stable five genotypes were CR 14B-180, NR 03 0155, GCO 174-1, COB 5-17, and TMS 07 0337 across the four locations. The genotypes COB15454, and CW444-30 were best for the Kebbi location, while NR030155 and TMS070337 were considered to be the best for the Otobi location. Genotype CR36-5 appeared to be the best for the Umudike area while genotype CW450-75 was best for the Kano location. This outcome revealed promising genotypes that can be suggested for site-specific cassava production.

Keywords: Stability, genetics, environment, Interaction, AMMI, semi-arid, cassava, and clones

Introduction

Cassava (*Manihot esculenta* Crantz) is a major staple food in Nigeria, consumed daily by more than 100 million people. The global production of cassava in 2014 was 278.7 million tons with an estimate of 281 million tons for 2015 and 288.4 million tons for 2016 (FAO, 2016). From available records, Nigeria still stands out as the world's largest producer of cassava with a progressive production pattern that increased from 42.5 million metric tons in 2010 to 54 million metric tons in 2012 with an average production output of 12.2 t/ha in 2010 increased to 14.03 t/ha in 2012 (FAOSTAT, 2013). The diverse uses of cassava largely explain its popularity in the tropics.

Cassava, however, shows a strong and significant genotype × environment interaction (G × E) effect (Fukuda, 1996) due to its diverse difficult cropping condition, thus making selection difficult. Breeding cassava for superior cultivars should be carried out considering the G×E effect. A detailed assessment of the magnitude and significance of G × E is important to ensure greater precision in the selection and release of high-yielding and stable clones (Kvitschal *et al*., 2009). Despite this important feature, it is common for cassava cultivars to display high sensitivity to differences in environmental conditions (Akinwale *et al.,* 2011). Nigerian agro-ecology is diverse and cassava is well adapted in many regions where this crop is grown, especially in the southern parts. However, it shows different growth and yield trends in different years as a result of soil and climatic variability in time and space. The water regime of an environment is another important factor which affects growth. Differential soil water and nutrient regimes have been reported to affect yield stability (Cock 1985). Although cassava is extremely tolerant to water stress, prolonged moisture deficiency leading to reduced growth, development, and root yield has been reported (CIAT, 1980; Connor *et al*., 1981; El-Sharkawy *et al.,* 1992).
Global warming as a result of greenhouse gases can also change the variability of climate. These changes

are effected through climate-related parameters which can trigger events of extreme cold and heat stress, drought with associated bushfires, pest outbreaks and ecosystem imbalance. Consequently, there is a need to evaluate cassava's response to different environments while identifying the indices that will enable the crop to adapt to changes in the environment in the coming decades (Egesi *et al.*, 2007). It is expected that the result from this study will help breeders in developing genotypes with improved tolerance to drier regions which would translate to increased cassava production and food security.

Materials and Methods

Twenty cassava clones were selected from the biotic/abiotic stress tolerance breeding population of the cassava programme of NRCRI, Umudike. The clones were obtained through hybridization and then raised from true seeds. Four check varieties namely; NR 03/0155, NR03/0211, NR 01/0004 and CR 36-5 were also added to the population. The trial was conducted in four locations, namely; the Institute of Agricultural Research (IAR) Out-Station at Minjibir Kano State, Kebbi State University of Science and Technology Aliero Kebbi State, NRCRI Sub-Station at Otobi Benue State and NRCRI Headquarters at Umudike Abia State. The trial was set up as a Randomized Complete Block Design (RCBD) with three replications in each location. Plot size of 20m^2(4m x 5m dimension i.e. 4 rows by 5 plants) was used with planting distance of 1m x 1m inter and intra row spacing giving a total plant population of 10,000 plants/ha. The trial was carried out in two planting seasons. The land was cleared, ploughed, harrowed and ridged using a tractor. Weeding was done at 5 weeks after planting (5WAP), 3 months after planting (3MAP) and 9 months after planting (9MAP). Fertilizer NPK 15:15:15 was applied 6 weeks after planting (6WAP) at the rate of 600kg/ha. Phenotypic traits were evaluated at the growing period of the plants and harvest. Qualitative traits were collected using visual ratings according to IITA standard operation practices; Plant vigour, Stay green ability of the leaves and Leaf retention. For quantitative traits, growth and fresh root yield and its related components were determined at harvest (12 MAP) from the ten inner plants of each plot. The data under this category were collected by observation and counting or by measurement. Data collected from the field trial were subjected to analysis of variance (ANOVA) using Genstat Discovery edition 12 (Genstat, 2012). The data were analysed as combined analyses using Split split-plot model in other to accommodate year and location effects, where the locations become the main plot and the genotypes as the subplots. The additive main effects and multiplicative interactions (AMMI) analysis was performed for visual examination of the GEI pattern of the data sets.

Results and Discussion

Across the environment, the combined analysis of variance (Table 2) revealed highly significant ($P < 0.001$) mean squares for yield and yield component traits for all the sources of variation. Genotypes (G), environment (E) and genotype by environment interaction (G×E) showed significant mean square ($P < 0.01$) for all traits under study such as DMC, STARCH, FRY, DRY and HI. Effects from G and E that showed a highly significant mean square revealed genotypic differences towards adaptation to different environments, thus the highly significant G×E effects show that the clones under study may be selected for adaptation to specific environments.

The range of their mean performance shows high variability among clones as revealed in (Table 3). Dry matter content ranged between 731.0281 (CW 52A-1) and 38.6432 (CW 45075), with starch ranging from 17.1397 (CTS 1A-311) and 27.2199 (CW 450 75). DRYD ranged between 5.42693 (CW 52A-1) and 9.5819 (NR 030155) while FRYD ranged from 16.13 (CW 450-75) and 33.0437 (CR- 14B-180). Harvest index (HI) ranged from 0.300815 (CW 450-75) to 0.378622 (COB 5-17). Genotype CW 450-75 had the highest dry matter content as well as starch but was low in fresh root yield and harvest index across locations as shown in (Table 3).

Results of correlation analysis showed a highly significant correlation ($P < 0.01$) between Dry matter content, starch and dry root yield (Table 4). Dry matter content is assumed to be one of the most important storage root components. Ntawuruhunga *et al.* (2001) reported that selection for dry matter content could be conducted without any serious effect on other yield components. Comparatively, the performance of the cultivars across locations revealed that CW 450 -75 had the best performance for dry matter content and starch content and could be ascribed as having stable performance.

Conclusion

The additive main effects and multiplicative interactions studies in eight environments show that AMMI analysis partitioned main effects into genotypes, environments and G × E, with all the components showing highly significant effects ($P < 0.01$). Principal Component axes 1 and 2 were significant ($P < 0.0001$ and 0.001). The two axes jointly explained the significant of the interaction sum of squares for dry matter content (19.40% and 69.75%), fresh root yield (17.86% and, 51.66%), starch (19.40% and 69.75%), dry root yield (12.22% and, 59.12%) and harvest index (24.70% and, 32.05%) respectively (Figs. 1, 2, 3, 4 and 5). The AMMI analyses for dry matter content, starch content, Dry root yield, and fresh root yield and harvest index are presented (Figures. 1, 2, 3, 4 and 5). According to the results of the AMMI study, the comparative performance of the clones across locations revealed that the best five stable genotypes were CR 14B-180, NR 03 0155, GCO 174-1, COB 5-17, and TMS 07 0337 across the four locations namely Kebbi, Otobi, Umudike and Kano for dry matter content, starch content, dry root yield, fresh root yield and harvest index. The genotypes COB154-54, and CW444-30 were best for the Kebbi location, while NR030155 and TMS070337 were considered to be the best for the Otobi location. Genotype CR36-5 appeared to be the best for the Umudike area while genotype CW450-75 was best for the Kano location. This result reveals promising genotypes that can be suggested for site-specific cassava production for arid and semi-arid agro-ecological regions in Nigeria.

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Table 1: Descriptions of the experimental sites

Location	State	Vegetation	Coordinates	Mean annual rainfall		Temperature	
				Max	Min	Max	Min
Minjibri	Kano	Sudan savannah	08^{0}30’ E 12^{0} 20’N	1000 mm	800 mm	39.I^{0}C	13.2^{0}C
Aliero	Kebbi	Sudan savannah	04^{0} 23’E 12^{0} 15’N	1300 mm	500 mm	40^{0} C	15^{0} C
Otobi	Benue	Guinea savannah	04^{0}53’ E 08^{0} 26’ N	1712 mm	800 mm	36 ^{0} C	21^{0} C
Umudike	Abia	Rainforest zone	07^{0} 33’E 05^{0} 29’N	2500 mm	1800 mm	33^{0} C	22^{0} C

Table 2: Combined analysis of variance for DMC, STARCH, FRY, DRY and HI

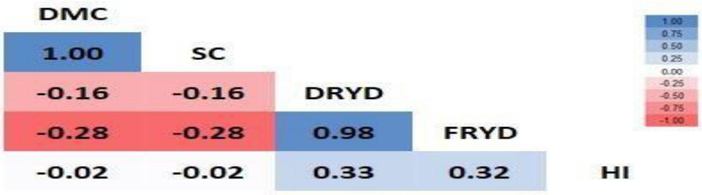
Source	DF	DMC	SC	DRYD	FRYD	HI
Total	575	69.9	124.0	38.5	332	0.00628
Treatments	191	80.7	143.2	66.4	633	0.00862
Genotypes	23	63.3	112.3	47.0	443	0.01042
Environments	7	562.1	996.5	1036.7	10965	0.07102
Block	16	84.0	148.9	45.0	294	0.00945
Interactions	161	62.3	110.5	27.0	211	0.00565
IPCA 1	29	241.2	427.8	88.5	604	0.01005
IPCA 2	27	72.1	127.8	19.7	224	0.00832
Residuals	105	10.4	18.4	11.8	98	0.00375
Error	365	64.2	113.9	23.9	178	0.00495

Df= degrees of freedom, fryd= fresh root yield, dryd= dry root yield, dmc= dry matter content, hi= harvest index

Table 3: Combined mean performance of selected cassava genotypes to yield and yield attributes across four locations in Nigeria

S/NO	GENOTYPE	DMC	STARCH	DRYD	FRYD	HI
1	COB 154-5-4	34.1867	21.2854	6.14704	19.6245	0.341911
2	COB 159-5-11	32.8604	19.5192	6.39551	19.3666	0.332374
3	COB 159-5-4	31.6947	17.9669	6.29222	20.3706	0.365632
4	COB 5-17	32.5344	19.0852	8.83868	28.6968	0.378622
5	CR 14B-180	32.5012	19.0409	10.5912	33.0437	0.395013
6	CR 36-5	32.6502	19.2393	9.18467	26.8432	0.335607
7	CTS 1A-311	31.0735	17.1397	7.23907	23.466	0.368212
8	CW 14B-218	33.2143	19.9904	8.28034	24.2352	0.36809
9	CW 444-30	35.9467	23.6291	5.5979	17.0104	0.323527
10	CW 450-75	38.6432	27.2199	5.68936	16.13	0.300815
11	CW 456-17	32.3065	18.7817	8.29071	26.7935	0.359929
12	CW 482-3	33.2917	20.0935	7.85748	24.5156	0.350926
13	CW 485-15	31.6294	17.8799	7.24539	23.1157	0.336615
14	CW52A-1	31.0281	17.0793	5.42693	17.7687	0.351557
15	GCO 174-1	32.2704	18.7336	9.37701	29.4025	0.365789
16	NR 01 0004	33.036	19.753	8.3036	25.8009	0.354464
17	NR 03 0155	32.545	19.0992	9.5819	29.619	0.365437
18	NR 03 0211	33.326	20.1392	7.72602	24.4462	0.362583
19	NR 05 0046	31.9729	18.3373	7.08212	23.5441	0.354875
20	NR 05 0067	32.0871	18.4894	8.10534	25.2834	0.33161
21	NR 05 0107	31.4856	17.6885	6.47583	21.6847	0.358493
22	TMS 01 0034	31.7012	17.9756	6.60847	22.1669	0.317483
23	TMS 07 0258	32.9629	19.6557	6.87846	21.1269	0.362028
24	TMS 07 0337	32.2888	18.7581	9.0933	28.1179	0.35322
	CV (%)	24.4	54.9	65.5	56.9	20.4
	MEAN	32.8	19.44	7.6	23.84	0.3515
	S.E.D	2.313	3.08	1.436	3.913	0.02069
	LSD	4.548	6.056	2.824	7.694	0.04068
	P-value	0.484	0.484	0.008	<.001	0.004

Table 4: Combined correlation table of yield and yield attributes across four locations in Nigeria



	DMC	SC	DRYD	FRYD
SC	1.00			
DRYD	-0.16	-0.16		
FRYD	-0.28	-0.28	0.98	
HI	-0.02	-0.02	0.33	0.32

1.00 0.75 0.50 0.25 0.00 -0.25 -0.50 -0.75 -1.00

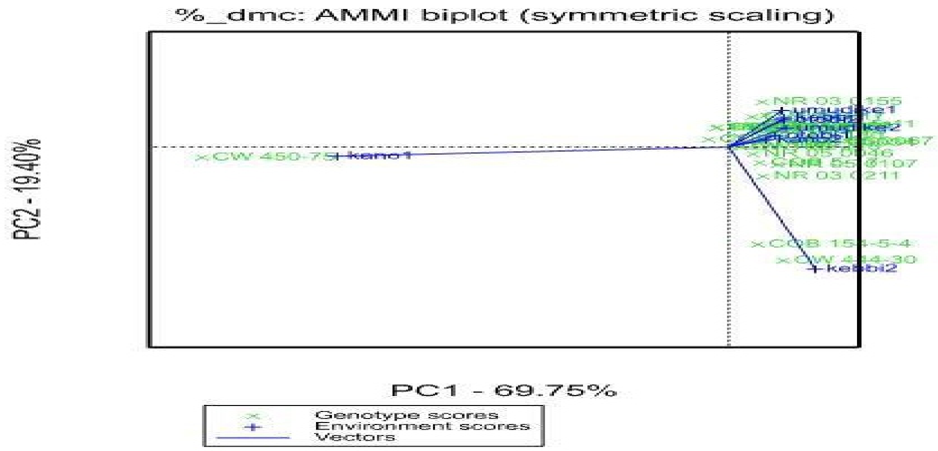
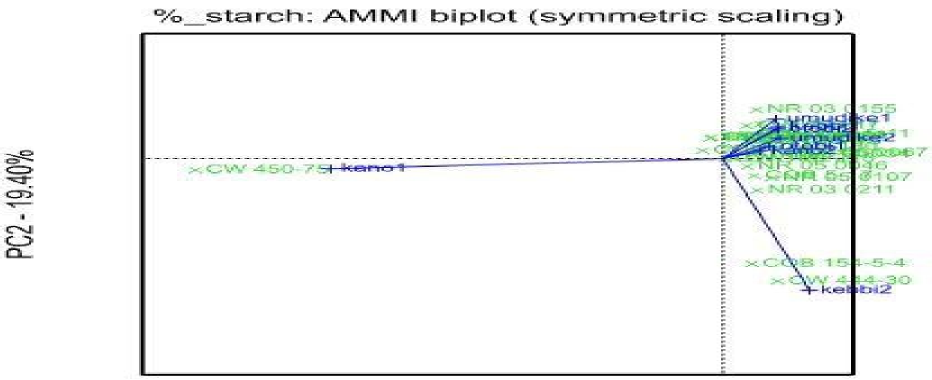


Fig. 1: Mean performance and stability of 24 cassava genotypes for dry matter content (DMC)



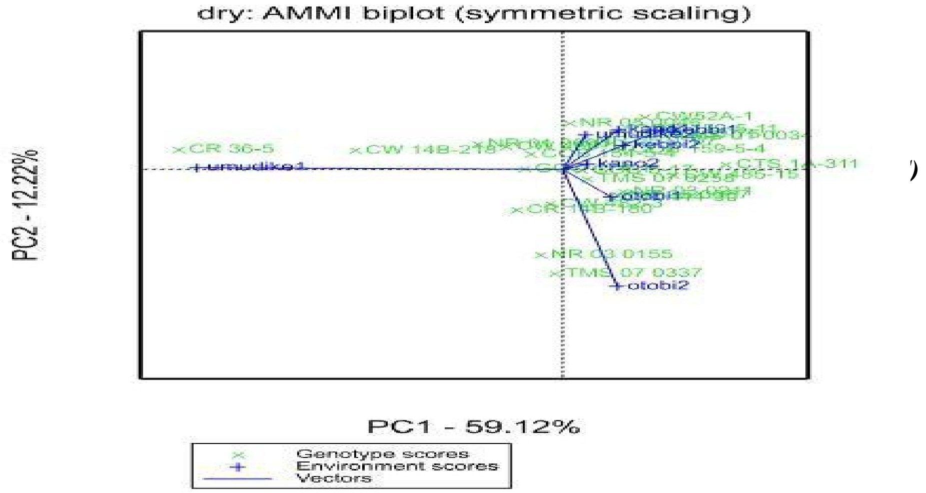


Fig. 3: Mean performance and stability of 24 cassava genotypes for dry root yield (DRYLD)

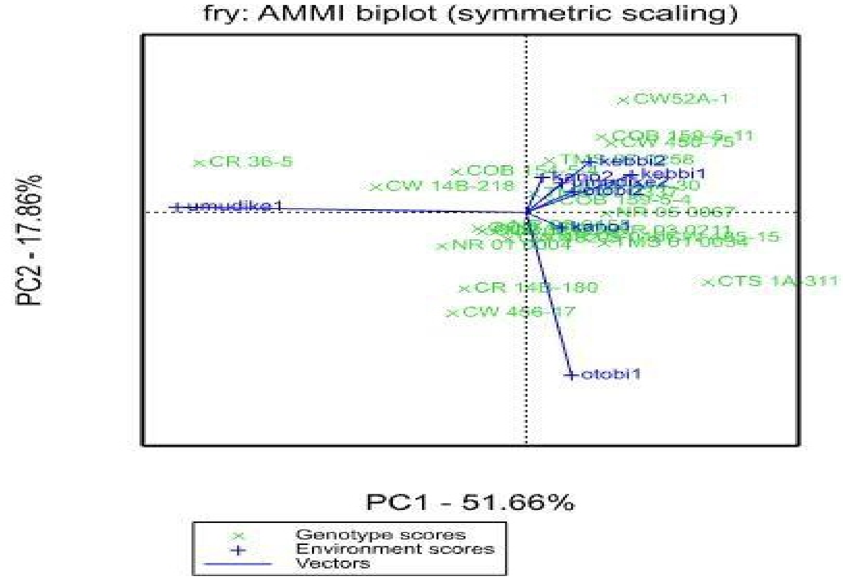


Fig. 4: Mean performance and stability of 24 cassava genotypes for fresh root yield (FRYLD)

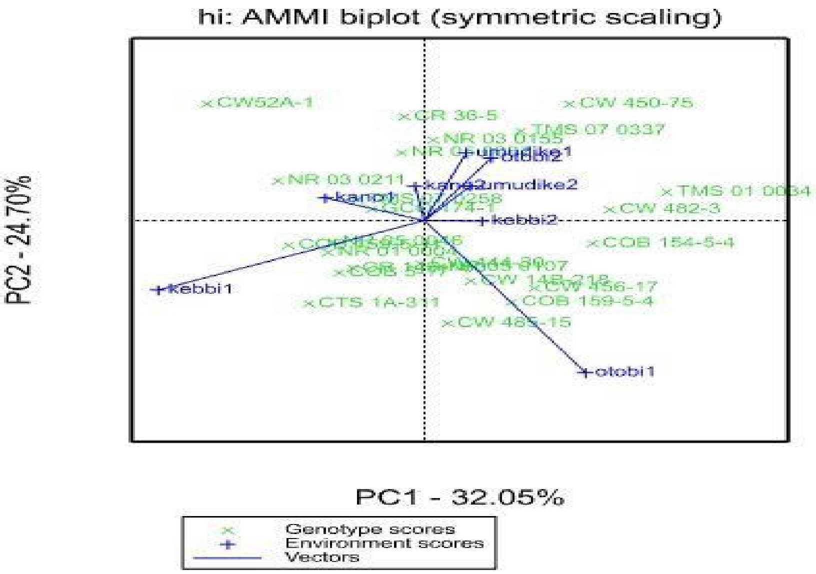


Fig. 5: Mean performance and stability of 24 cassava genotypes for harvest Index (HI)