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Original Article

Evaluation of Drought Tolerant Top Cross and Three-Way Cross Maize Hybrids for Grain Yield and Related Traits in Three Agro-Ecological Zones of Southwest Nigeria

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Abstract

Superiority of hybrid maize cannot be overemphasized. Different types of hybrids are developed by plant breeders to improve productivity and multi-locational evaluation of these hybrids prior to release is necessary to select the best. The objectives of this study were to identify maize hybrids with superior agronomic potentials and compare the performance of top-cross and three-way cross hybrid maize varieties for grain yield and related traits under rain-fed condition in three different locations (Abeokuta, Ibadan and Akure) of Southwest Nigeria. The study consisted of ten hybrids each of top-cross and three-way cross hybrid varieties, tested with two checks. At each location, the experiment was laid out in randomised complete block design with three replications. The results showed that effects of locations, genotypes and genotype x location interactions were highly significant ($p<0.01$) for all the traits evaluated. Significant differences were also revealed between the top-cross and three-way cross hybrids for all the traits evaluated except days to 50% tasseling, ear diameter and 100-grain weight. The top-cross hybrids were superior over the three-way cross hybrids for grain yield by 5.25%. The hybrids 'M0926-7', 'M0926-8', 'M1026-11', 'M1026-3', 'M1226-2' (top-cross hybrids), 'M1124-24', 'M1124-27', 'M1124-31', 'M1227-6' and 'M1227-7' (three-way cross hybrids) showed highest stable yields across the three locations. Hybrids 'M0926-7' (top-cross hybrid) and 'M1124-24' (three-way cross hybrid) that expressed early flowering with higher grain yield are recommended for drought stress prone areas because of their abilities to tolerate drought through escape.

Keywords: drought tolerance; grain yield; hybrids; three-way cross; top-cross

Introduction

Maize (*Zea mays* L.) is an important cereal that is mainly used for food and feed in many parts of Africa. The importance of maize cannot be over-emphasised. Its prospects over others are overwhelming, it is proposed to be the highest produced crop in the world by 2025 and demand for it would be doubled by 2050 in the developing countries (CIMMYT and IITA, 2010). Presently, in larger parts of Sub-Sahara Africa (SSA), maize is the principal staple crop, covering a total of nearly 27 million ha (FAO, 2010). It accounts for 30% of the total area under cereal production in this region: 19% in West Africa, 61% in Central Africa, 29% in Eastern Africa and 65% in Southern Africa (FAO, 2010). In Southern Africa, maize is particularly important, accounting for over 30% of the total calories and protein consumed (FAO, 2010). According to Dowswell *et al.* (1996), maize has been put to a wide range of uses than any other cereal: as human food, feed grain, fodder crop, and for many industrial purposes because of it broad global distribution, its low price relative to other cereals, its diverse grain types, and its wide range of biological and industrial properties.

In Nigeria, it is mainly cultivated in almost all agro-ecology of the nation and it has almost replaced traditionally grown cereals such as sorghum particularly in the northern savannah agro-ecological zone (Iken and Amusa, 2004). Nigeria is the largest producer of maize in SSA and accounted for 0.9% of the world production in 2010 (FAOSTAT, 2013). This leadership in SSA has been attributed to extensive rather than intensive as it is obtainable in developed countries. In Nigeria yield per hectare ranges from 1.27 to 2.20 ton/ha while the USA is already having up to 10.34 ton/ha (FAOSTAT, 2013). Significant potential improvements in yield could be achieved through the use of hybrid maize varieties. The developed countries make use of hybrid maize whereas the

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developing countries do not, thus the drastic differences in yield. Hybrids are major contributor to higher yield in maize and are generally high yielding than open-pollinated maize varieties, if grown under suitable conditions. The yield increase of the numerous types of hybrids over the open pollinated varieties (OPVs) was outlined by Paliwal (2000) illustrating 46% for single cross, 30% for three-way cross, 23% for double cross, 37% for double top cross, 28% for top cross, and 17% for variety cross.

One of the major limiting factors of maize production in Nigeria is drought. The irregular distribution of rains due to climatic variations within each particular region causes drought of variable intensities. It has been estimated that drought problems depending on year and intensity reduce maize production by 14% to 28% (Santos *et al.*, 1996). Considering the importance and rising demand of maize as a feed and staple food in Nigeria and SSA as a whole, staggering yield losses due to drought could threatens the food security of this region. Consequently, improved high yielding maize variety can express its full genetic potential only when offered optimum management resources (Iken and Amusa, 2004). However, the use of drought tolerant cultivars is not a guarantee that yield potential is fully expressed by a hybrid. Other factors, such as, low soil fertility, can greatly influence yield as well (Santos *et al.*, 2006).

For breeding stress-tolerant maize, selection can be either conducted directly under stress, indirectly under optimal conditions, or under both optimal and stress conditions (Byrne *et al.*, 1995). Therefore, this study aimed at the indirect selection of maize hybrids under rain-fed condition in three different locations of South-Western Nigeria with the following objectives: (i) to identify hybrids with superior yield and agronomic traits potentials, and (ii) to compare the performance of top-cross and three-way cross hybrid maize varieties for grain yield and yield-related traits.

Materials and Methods

The study was carried out at three different locations of South-Western Nigeria during the wet cropping season of 2014. The locations were the Teaching and Research Farm of The Federal University of Agriculture, Abeokuta, Ogun State (7°14' N, 3° 26' E, and 162 masl); National Institute of Horticultural Research, Ibadan, Oyo State (7°0 24' N, 3°0 50' E, and 184 masl) and Teaching and Research Farm of The Federal University of Technology, Akure, Ondo State (7° 18' N, 5° 07' E, and 380 masl). The mean monthly rainfall (mm) and temperature (°C) during the period of experimentation (August-November) are shown in Table 1. The experimental materials sourced from the gene bank of the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria comprised ten Top-cross Drought Tolerance and Striga Resistance (DTSTR), ten Three-way cross Drought Tolerance (DT) maize hybrids and two (2) checks (Table 2). At each location, the soil was mechanically ploughed and harrowed. The trials were laid out in randomised complete block design with three replications. Each hybrid was planted in a two-row plot of 5 m long, at a spacing of 75 cm x 50 cm. Three seeds per hole were planted and later thinned to two plants per hole. A compound fertilizer of NPK 15:15:15 was applied at the rates of 60 kg N, 60 kg P and 60 kg K_2O ha^{-1} at two weeks after planting. An additional 60 kg N ha^{-1} was also applied as top dressing six weeks after planting (WAP) using urea (46%N). Other crop management practices were applied following the standard recommendations at each location. Sowing of seeds was done on 7th, 9th and 21st August, 2014 at Ibadan, Akure and Abeokuta, respectively. Data were collected on days to 50% anthesis (DPOL), days to 50% silking (DSLK), plant height (PLHT), ear height (EHT), field weight (FDWT), ear length (ELTH), ear diameter (EDMT), number of kernel rows per cob (KROW), 100-grain weight (GWT), moisture content and grain yield (YLD).

Grain yield in $kgha^{-1}$ (later converted into t/ha) was calculated for every entry from the data of field weight per plot using the following formula (Rahman *et al.*, 2007):

Grain yield ($kgha^{-1}$)=Field weight(kg/plot)×(100-MC)×0.8×10,000/(100-12)×7.5

Where: MC= moisture content of grains at harvest (%), 0.8= shelling co-efficient, 7.5 = area harvested $plot^{-1}$ (m^2), 1 hectare = 10,000 m^2 and 12% = moisture content required in maize grain at storage. Data collected were subjected to analysis of variance using SAS software version 9.1 (SAS Institute, 2000) for each location and combined locations. The mean values of traits for the hybrids were compared using Duncan's Multiple Range Test (DMRT) at significant level of 0.05. The contrasts between the hybrids populations were also compared using confidence intervals for differences in means, at 95% confidence level.

Table 1. Mean monthly rainfall (mm) and temperature (°C) of the test locations during the wet cropping season of 2014

	Abeokuta		Ibadan		Akure	
	Rainfall (mm)	Temperature (°C)	Rainfall (mm)	Temperature (°C)	Rainfall (mm)	Temperature (°C)
August	93	26	139	25	114	25
September	161	26	139	26	207	26
October	206	26	151	27	206	27
November	18	28	52	28	157	28

Sources:
Department of Agro-meteorological and Water Management, Federal University of Agriculture, Abeokuta.
National Horticultural Research Institute, Ibadan, Oyo State.
AccuWeather.com for Akure.

Table 2. Description of maize hybrids evaluated during the wet cropping season of 2014

Hybrid	Pedigree	Kernel Colour
	Top-cross DTSTR	
M0926-7	White DTSTRSyn/IWD-SYN-STR-C3-46-5-BB	White
M0926-8	White DTSTRSyn/IWD-SYN-STR-C3-51-1-B	White
M0926-9	White DTSTRSyn/IWD-SYN-STR-C3-52-2-B	White
M1026-1	IWDC2SynF2/1368xMi82-23-2-1-1-B*7	White
M1026-11	White DTSTRSyn/IWD-SYN-STR-C3-52-4-B	White
M1026-13	White DTSTRSyn/IWD-SYN-STR-C3-70-2-B	White
M1026-2	IWDC2SynF2/1368xMi82-23-2-1-4-B*6	White
M1026-3	IWDC2SYN/P43SRC9FS100-1-1-8-#1-B1-13-B1-B*8	White
M1026-4	White DTSTRSyn/P43SRC9FS100-1-1-8-#1-B1-13-B1B*8	White
M1226-2	DTSTR-WSYN2/IWD-SYN-STR-C3--52-3-BB	White
	Three-way cross DT	
M1124-17	(1368/Mi82-23-2-1-2-B*7/P43SRC9FS100-1-1-8-#1-B1-13-B1-B*6)-1-1/((ACR-86-8-1-2-1-1-1-B-1-B*4/(Babangoyo/MO17LPA/Babangoyo-28-1-2-1-B*6))-38-1/IWD-SYN-STR-C3--70-2-BB	White
M1124-24	(1368/Mi82-23-2-1-2-B*7/P43SRC9FS100-1-1-8-#1-B1-13-B1-B*6)-65-1/DTPL-W-C7-S2-7-1-1-1-1-B-2-B*4/BabangoyoxMO17LPAxBabangoyo-23-1-3-1-B*6-23-1/IWD-SYN-STR-C3--35-3-BB	White
M1124-27	(1368/Mi82-23-2-1-2-B*7/P43SRC9FS100-1-1-8-#1-B1-13-B1-B*6)-58-1/DTPL-W-C7-S2-7-1-1-1-1-B-2-B*4/BabangoyoxMO17LPAxBabangoyo-23-1-3-1-B*6-9-1/IWD-SYN-STR-C3--51-1-BB	White
M1124-29	(1368/Mi82-28-1-1-2-B*7/P43SRC9FS100-1-1-8-#1-B1-13-B1-B*6)-40-1/DTPL-W-C7-S2-1-2-1-1-5-B-1-B*4/BabangoyoxMO17LPAxBabangoyo-23-4-3-3-B*6-46-1/IWD-SYN-STR-C3--51-1-BB	White
M1124-31	(KU1409/KU1414-SR/A619)-S2-2/9450xKI21-7-2-2-1-1-BB/(POP66SR/ACR91SUWAN1-SRC1/ACR91SUWAN1-SRC1-6X(MP420x4001xMP420)-3-1-3-1-B)S2-5-B*5	Yellow
M1227-14	(KU1409/KU1414-SR/KVI3)-S2-4-1-BB/9450xKI21-1-5-2-1-2-B*5/(SYN-Y-STR-34-1-1-1-1-2-1-B*5/NC354/SYN-Y-STR-34-1-1-1-1-2-1-B*5)-S2-7-5-BB-B-B-B-B	Yellow
M1227-18	(KU1409/KU1414-SR/A619)-S2-3-B/9450xKI 21-1-4-1-1-2-B-B-B-B-B/(POP66SR/ACR91SUWAN1-SRC1/ACR91SUWAN1-SRC1-6X(MP420x4001xMP420)-3-1-3-1-B)S2-5-BB-B-B-B-B	Yellow
M1227-21	9450xKI 21-7-2-2-1-1-B-B-B-B-B/(KU1409/KU1414-SR/NC350)-S2-24-1-BB/(POP66SR/ACR91SUWAN1-SRC1/ACR91SUWAN1-SRC1-6X(MP420x4001xMP420)-3-1-3-1-B)S2-10-BB-B	Yellow
M1227-6	1368 x Mi82-33-1-1-B-B-B-B-B-B/LATA-26-1-1-1-B-B-B-B-B-B-B/IWD-SYN-STR-C3--52-3-B-B-B	White
M1227-7	1368xHIx4269-1x1368-7-1-B-B-B-B-B-B-B-B-B/DTPL-W-C7-S2-1-2-1-1-5-B-1-B-B-B-B-B/IWD-SYN-STR-C3--47-1-B-B-B	White
	Checks	
SUWAN-ISR (non-hybrid Check)	Population (streak resistant introduced from Thailand)	Yellow (OPV)
Oba Super 2 (hybrid Check)	KU1414SR\4001	Yellow

Source: International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria

Results

Mean squares from analysis of variance for each location and combined location presented in Table 3 showed that the effects of genotypes, locations and genotype x environment interactions were highly significant ($p<0.01$) for all the traits evaluated. The mean performances of the hybrids for Abeokuta, Ibadan and Akure are presented in Tables 4, 5 and 6, respectively. It took the earliest flowering hybrid 'M1124-24' 54, 53 and 60.67 days to attain 50% anthesis and 56, 55.6 and 62.67 days to attain 50% silking in Abeokuta, Ibadan and Akure, respectively, except in Abeokuta the hybrid had above average in field weight and grain yield. Hybrids 'M1026-4' (63.67 days) and 'M1026-1' (64.67 days) had the highest number of days to 50% anthesis in Ibadan and Akure respectively and both attained 50% silking in 67 days at both locations. While at Abeokuta the highest days to 50% anthesis and silking were observed in 'M1227-18' (60 days) and 'M1026-13' (62.67 days) respectively. Hybrids 'M0926-8' (234.67 cm), 'M1026-13' (208.0 cm) and 'M0926-7' (214.67 cm) were the tallest in Abeokuta, Ibadan and Akure respectively. Consistently, hybrid 'M1124-17' recorded very short plant and ear heights across the locations. Also this hybrid had below average yield in Abeokuta and Akure. In Ibadan, hybrids 'M1026-3' (7.40 kg) and 'M0926-8' (7.90t/ha) had the highest field weight and grain yield, respectively while the lowest field weight (3.77 kg) and grain yield (3.60 t/ha) were recorded for non-hybrid check 'SUWAN-1SR'. Also in Akure hybrid 'M0926-8' had the highest field weight (9.60 kg) and grain yield (9.37 t/ha) whereas hybrid 'M1227-14' had the lowest field weight (3.97 kg) and grain yield (3.87t/ha). While hybrids 'M1227-6' and 'M1227-2' had the highest and the lowest values for field weight and grain yield in Abeokuta respectively.

The combined mean performance of the hybrids for ten traits across the locations is presented in Table 7. Results revealed that hybrid 'M0926-8' had the highest grain yield (7.9 t/ha), field weight (7.8 kg) and ear height (107.3 cm). The highest 100-grain weight (35.6 g), ear length (20.1 cm) and highest days to 50% silking (63.9 days) were observed in hybrid 'M1026-4', whereas hybrid 'M1026-1' (61.7 days) and 'M1026-4' (61.6 days) had the highest days to 50% anthesis. Hybrid 'M1026-13', 'M1226-2' and 'M1227-6' had the highest plant height (212 cm), number of kernel rows per cob (16.5) and ear diameter (51.0 mm) respectively. Conversely, hybrid 'M1227-21' had the least grain yield (4.5 t/ha), field weight (4.6 kg), 100-grain weight (23.6 g) and ear diameter (45.1 mm). The shortest plant and ear heights (175.4 cm and 70.3 cm) were expressed in hybrid 'M1124-17' and the lowest days to 50% anthesis (55.9 days) and silking (58.1 days) were observed in hybrid 'M1124-24'. Hybrids 'M1026-1' and 'M0926-9' had the least number of kernel rows per cob (12.2) and ear length (14.5 cm), respectively. The best hybrids combined across the three locations were 'M0926-7', 'M0926-8', 'M1026-11', 'M1026-3', 'M1226-2', 'M1124-24', 'M1124-27', 'M1124-31', 'M1227-6' and 'M1227-7'. These hybrids had mean grain yield above the grand mean of 5.8 t/ha. Both checks SUWAN-1SR (5.1 t/ha) and Oba Super 2 (4.7 t/ha) had grain yield below the grand mean (5.8 t/ha)

Significant ($p \leq 0.05$) differences were observed between the top-cross and three-way cross hybrids for days to 50% silking, plant height, ear height, ear length, number of kernel rows per cob, field weight and grain yield (Table 8). However, there were no significant differences observed between the two hybrid populations for days to 50% anthesis, ear diameter and 100-grain weight. Averaged over the three locations, through the analysis of means and confidence intervals, it was observed that the top-cross hybrids had higher grain yield than three-way cross hybrids by 5.25%. Generally, 65% of the hybrids (top-cross and three-way cross) out-yielded the best local check (SUWAN-1SR) by 5% to 48%. The best top-cross hybrid (M0926-8) out-yielded the best local check (SUWAN-1SR) by 48%, while that of the three-way cross hybrids (M1124-31 and M1227-6) out-yielded the local check by 31%.

Table 3. Analysis of variance showing mean squares of the 20 hybrids with two checks for ten traits at Abeokuta, Ibadan, Akure and combined locations

Source	DF	Days to anthesis (days)	Days to silking (days)	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear diameter (mm)	Number of Kernel rows cob^{-1}	100-Grain weight (g)	Field weight (kg)	Grain yield (t/ha)
						Abeokuta					
Replication	2	0.05	0.05	41.05	91.77	0.64	0.46	0.07	0.59	0.42	0.60
Genotype	21	5.16**	8.40**	415.96**	269.67**	7.12**	6.79**	2.73**	34.37**	4.51**	4.00**
Error	42	1.17	1.81	33.82	41.71	0.41	1.01	0.29	1.73	0.63	0.59
						Ibadan					
Replication	2	0.47	1.47	6.11	4.92	2.26**	0.11	0.07	0.47	0.06	0.05
Genotype	21	13.99**	18.14**	493.01**	309.39**	7.32**	7.36**	3.21**	35.55**	2.98**	3.29**
Error	42	1.09	1.69	29.39	21.77	0.47	0.42	0.17	3.12	0.32	0.24
						Akure					
Replication	2	0.95	1.70	70.92	1.56	0.31	3.27	0.39	1.38	0.06	0.02
Genotype	21	3.22**	3.79**	630.11**	389.79**	7.98**	15.99**	9.75**	27.23**	6.07**	5.70**
Error	42	0.91	1.40	23.83	21.23	0.30	2.47	0.41	2.43	1.00	0.91
						Combined locations					
Location (Loc)	2	413.49**	357.56**	19961.20**	6916.38**	37.12**	4.11**	16.05**	449.88**	9.06**	10.95**
Genotype (Gen)	21	14.82**	18.33**	1221.90**	751.97**	18.57**	20.51**	11.18**	77.04**	8.18**	8.06**
Rep (Loc)	6	0.49	0.95	28.50	10.38	0.41	1.072	0.13	1.04	0.13	0.11
Gen. X Loc.	42	3.78**	5.82**	189.70**	117.86**	2.18**	6.76**	2.33**	10.72**	2.13**	1.94**
Error	126	1.06	1.51	17.20	15.51	0.25	0.67	0.25	1.76	0.49	0.44

** Significant at 0.01 probability level, DF= degree of freedom

Table 4. Mean performance of the 20 hybrids with two checks for ten traits evaluated at Abeokuta

Genotypes	Days to anthesis (days)	Days to silking (days)	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear diameter (mm)	Number of Kernel rows cob^{-1}	100-Grain weight (g)	Field weight (kg)	Grain yield (t/ha)
SUWAN1-SR	55ef	58b-d	228.33a-c	103a-c	16.57d-h	48.37a-e	13.77c-g	32.67b-e	4.37d-g	4.17d-g
Oba Super 2	57b-d	61.67a-c	202.67ef	96.33a-e	16.93c-g	46.6d-f	12.9fg	28.67e-i	4.23e-g	4.03e-g
M0926-7	56d-f	57.67cd	203ef	90b-e	16.17e-h	49.17a-d	15a-d	31b-f	6.8a-d	6.5a-d
M0926-8	57b-e	58b-d	234.67a	108ab	15.4f-i	46.47d-f	15a-d	30d-g	6.7a-e	6.4a-e
M0926-9	57b-e	61a-c	205d-f	86.67c-e	14i	47.3c-f	15.3a-d	25.67h-j	4.77c-g	4.57c-g
M1026-1	59ab	61a-c	218.33a-e	97a-e	17.37b-f	46.9d-f	12.37g	34.67a-c	4.7c-g	4.47c-g
M1026-11	57b-e	58.67a-d	232.67ab	106a-c	16.27e-h	50.97a	16.37a	30d-g	6.27c-g	6a-g
M1026-13	59ab	62.67a	227a-c	103a-c	17.67a-e	45.27ef	14b-g	30d-g	5.1b-g	4.9b-g
M1026-2	57b-e	59.67a-d	204ef	78.67e	16.67d-g	48.2a-e	15.67ab	24.67-j	4.17fg	3.97fg
M1026-3	58a-c	61a-c	232.67ab	103.67a-c	19.6a	50.67ab	14.67b-e	37a	6.37a-g	6.07a-g
M1026-4	58a-c	59.67a-d	222.67a-d	95.67a-e	19.07ab	47.6b-f	14.37b-f	35ab	5.87a-g	5.6a-g
M1226-2	57b-e	58.67a-d	205d-f	91.67a-e	16.4e-h	48.57a-d	15a-d	28f-i	6.67a-e	6.4a-e
M1124-17	57b-e	58b-d	198.67f	81.67de	17.67a-e	48.6a-d	13.67d-g	30.67c-f	4.3efg	4.6c-g
M1124-24	54f	56d	205d-f	81de	14.6hi	48a-f	13e-f	33a-d	5.27b-g	5.07b-g
M1124-27	56c-e	58.67a-d	201ef	96a-e	15.67e-i	50.2a-c	14.37b-f	31.67b-f	7.07a-c	6.7a-c
M1124-29	58a-c	61a-c	201.67ef	88b-e	14.07i	48.5a-d	14.67b-e	28.67e-i	4.1fg	3.9fg
M1124-31	58a-c	60.67a-c	213.67c-f	106.67a-c	18.87a-c	48.6a-d	14b-g	29.67d-h	7.47ab	7.2ab
M1227-14	58a-c	60.67a-c	213c-f	111.67a	16e-i	48a-f	13.7c-g	32b-f	6.47a-f	6.2a-f
M1227-18	60a	62ab	206d-f	104.67a-c	18.5a-d	47.67b-f	14.3b-f	31b-f	5.07b-g	4.87b-g
M1227-21	58a-d	59a-d	207d-f	89.67b-e	15g-i	44.97f	14.67b-e	23j	3.9g	3.77g
M1227-6	57b-e	58.67a-d	205d-f	100a-d	16.1e-h	48.77a-d	15.37a-c	26g-j	7.9a	7.57a
M1227-7	59ab	60.67a-c	216b-f	104a-c	16.4e-h	48.8a-d	13.67d-g	30d-g	6.37a-g	6.07a-g
Mean	57.23	59.68	212.86	96.5	16.59	48.1	14.35	30.14	5.63	5.41
SE ±	0.19	0.24	0.21	1.33	0.2	0.17	0.43	0.13	1.54	0.16
CV	1.89	2.25	2.73	6.69	3.88	2.09	3.76	4.37	14.06	14.24

Means followed by the same letter (s) in the same column are not significantly different at $p \leq 0.05$ based on DMRT

Table 5. Mean performance of the 20 hybrids with two checks for ten traits evaluated at Ibadan

Genotypes	Days to anthesis (days)	Days to silking (days)	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear diameter (mm)	Number of Kernel rows cob-1	100-Grain weight (g)	Field weight (kg)	Grain yield (t/ha)
SUWAN1-SR	58f	60.67ef	178.33cde	78d-g	16.83def	49.67bc	13.3d-g	34.33bcd	3.77f	3.6g
Oba Super 2	61.33bcd	64.33bc	168.67efg	74gh	16.97def	48.1efg	13.63c-g	32.33cde	4.07ef	3.9fg
M0926-7	58f	60f	196.67b	85.33bcd	16.5efg	49.5bcd	15.67a	30.67c-f	6.4a-d	6.17bcd
M0926-8	62ab	64.67b	187c	103a	15.77f-i	48.57c-f	15ab	36abc	7.2ab	7.9a
M0926-9	58.67f	62c-f	181.67cd	74gh	13.77j	47.57e-h	15ab	30def	4.1ef	3.9fg
M1026-1	61.67bc	64bcd	183.67cd	77.67d-g	18bcd	48.57c-f	12.37g	39.67ab	5.67a-e	5.3c-f
M1026-11	58.67f	61ef	187c	83.67cde	15i	48.8b-e	14b-f	27.67ef	7.1ab	6.8abc
M1026-13	58.67f	62c-f	208a	92.67b	18.6b	46.07i	14.37a-d	32cde	6.5a-d	6.3bc
M1026-2	59.67def	62.67b-e	175def	65ij	15.9f-i	47.47fgh	13.67c-g	31.67cde	5.5b-f	5.3c-f
M1026-3	60.67b-e	63.67bcd	198b	83c-f	18.27bc	48.4def	12.37g	34.67bcd	7.4a	7.1ab
M1026-4	63.67a	67a	184.67cd	71.67ghi	19.9a	46.97ghi	13efg	40.67a	6.2a-d	5.97b-e
M1226-2	59ef	61.67def	163.67g	71ghi	16.4e-h	49.77b	15.17ab	31.67cde	6a-d	5.8b-e
M1124-17	58f	59.67f	162.67g	58.67j	15.9f-i	48.27ef	12.7fg	35.67abc	6a-d	5.8b-e
M1124-24	53g	55.67g	177c-f	71.67ghi	15.2ghi	48.17ef	12.37g	35.67abc	6.1a-d	5.87b-e
M1124-27	59ef	60f	162g	65ij	16f-i	51.9a	14.2b-e	33cde	5.6b-e	5.4c-f
M1124-29	58f	59.67f	159.67g	67.67hi	15.1hi	49.87b	14.37a-d	34cd	5.6b-e	5.37c-f
M1124-31	62ab	64.67b	167fg	74.67fgh	18.27bc	46.17i	13efg	30.67c-f	6.5a-d	6.2bcd
M1227-14	61bcd	64bcd	179cd	87.67bc	15.1hi	47.57e-h	13.67c-g	30.67c-f	4.9c-f	4.77d-g
M1227-18	60.67b-e	63b-e	177c-f	88bc	18.97ab	48.37def	14.37a-d	31c-f	5.8a-e	5.6b-e
M1227-21	58.67f	59.67f	176.67c-f	75.67e-h	16.37e-h	46.7hi	14.37a-d	25.67f	4.77def	4.57efg
M1227-6	60c-f	63b-e	161g	71.67ghi	14.77ij	51.97a	15.67a	33cde	6.3a-d	6.07b-e
M1227-7	59ef	60.67ef	175def	78d-g	17.3cde	49.9b	14.7abc	33.67cd	6.6abc	6.37bc
Mean	59.52	61.98	177.7	77.17	16.58	48.56	13.95	32.92	5.82	5.64
SE ±	0.28	0.33	0.2	1.32	0.2	0.13	0.45	0.13	1.64	0.14
CV	1.75	2.10	3.05	6.05	4.12	1.33	2.99	5.37	9.66	8.67

Means followed by the same letter (s) in the same column are not significantly different at p≤0.05 based on DMRT

Table 6. Mean performance of the 20 hybrids with two checks for ten traits evaluated at Akure

Genotypes	Days to anthesis (days)	Days to silking (days)	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear diameter (mm)	Number of Kernel rows cob-1	100-Grain weight (g)	Field weight (kg)	Grain yield (t/ha)
SUWAN1-SR	60.67d	62.33f	200.67bcd	96.33b	17.53efg	46ef	14.43ghi	32.67a	5.47e-i	5.37d-h
Oba Super 2	62bcd	64.67b-f	186.67fgh	93bc	18.43de	47.27cde	13.13jkl	30.67a-d	4.6hi	4.5gh
M0926-7	62bcd	63.67def	214.67a	97b	17.17fg	51ab	15.67def	26.67ef	8.4ab	8.2ab
M0926-8	62bcd	63.67def	201.67bcd	111a	16.9gh	51.77a	18b	25.67fg	9.6a	9.37a
M0926-9	61.67cd	64c-f	205bc	86.67cde	15.77i	49.7a-d	16c-f	25fgh	6.27d-h	6.07c-g
M1026-1	64.67a	67a	198cde	68gh	19.6c	46.3ef	12l	30.67a-d	5.97d-h	5.8c-g
M1026-11	62bcd	63.67def	204bcd	89bcd	18.57d	51.07ab	16.3cde	25.67fg	7.4b-e	7.2bcd
M1026-13	63.67ab	66abc	201bcd	89.67bcd	20.47bc	45.87ef	13.67ijk	22.67hi	5.17ghi	5fgh
M1026-2	62bcd	64c-f	173.67jkl	68gh	16hi	46.97de	16.67cd	23ghi	5.4f-i	5.27e-h
M1026-3	62bcd	63.67def	205bc	83.67de	21.93a	48.47b-e	13.67ijk	31.67ab	8.27abc	8.07ab
M1026-4	63abc	65a-e	209ab	87cde	21.2ab	46.37ef	13jkl	31abc	5ghi	4.9fgh
M1226-2	61.67cd	64.67b-f	195def	84de	17.67d-g	51.07ab	19.37a	26ef	6.7b-g	6.57b-f
M1124-17	61.67cd	63.67def	165l	70.67gh	16hi	46.2ef	13.67ijk	30.67a-d	5.57d-i	5.4d-h
M1124-24	60.67d	62.67ef	175ijk	65h	17.3fg	50.1abc	15fgh	30.67a-d	8.4ab	8.17ab
M1124-27	61.67cd	63.33def	169.67jkl	69gh	17.6d-g	50.2abc	15fgh	28def	5.9d-i	5.7c-g
M1124-29	62bcd	64.67b-f	167.67kl	79ef	17.37fg	47.6cde	15.67def	28def	6.17d-h	5.97c-g
M1124-31	62.67bc	64.33b-f	190.67efg	91.67bcd	17.77d-g	46.97de	12.67kl	28def	7.5bcd	7.3bc
M1227-14	61.67cd	65.33a-d	196cde	83de	16.93gh	47de	15.3efg	29.67bcd	3.97i	3.87h
M1227-18	63abc	65a-e	178hij	79ef	18def	47.6cde	14hij	28.67cde	5.57d-i	5.8c-g
M1227-21	64.67a	66.33ab	184.67gh	73.67fg	16.7ghi	43.67f	15.37efg	22i	5.2ghi	5.1fgh
M1227-6	62bcd	64c-f	183.67ghi	90bcd	16.87gh	52.17a	17bc	28def	7.2b-f	7b-e
M1227-7	61.67cd	64.67b-f	183ghi	84de	16.97fgh	49.5a-d	14hij	27.67def	6.47c-h	6.27c-g
Mean	62.23	64.38	190.35	83.56	17.85	48.31	14.98	27.85	6.37	6.22
SE ±	0.16	0.18	0.32	1.45	0.21	0.2	0.4	0.23	1.83	0.19
CV	1.53	1.83	2.56	5.51	3.07	3.26	4.27	5.59	15.70	15.35

Means followed by the same letter (s) in the same column are not significantly different at p≤0.05 based on DMRT

Table 7. Mean performance of the 20 hybrids with two checks for ten traits evaluated at Abeokuta, Ibadan and Akure combined

Genotypes	Days to anthesis (days)	Days to silking (days)	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear diameter (mm)	Number of Kernel rows cob^{-1}	100-Grain weight (g)	Field weight (kg)	Grain yield (t/ha)
SUWAN1-SR	57.9de	60.7ef	203.6b-d	94.4b	17.0de	47.6g-i	13.6fg	33.3bc	5.3f-h	5.1f-h
Oba Super 2	60.2a-d	63.6ab	183.8fg	91.6b-d	17.6cd	47.8f-i	13.3fg	31.8cd	4.9gh	4.7gh
M0926-7	58.6cd	60.4f	204.8a-c	90.8b-d	16.6e-h	49.9a-d	15.4bc	29.4e-h	7.2a-c	7.0b
M0926-8	60.3abc	62.1b-f	207.8ab	107.3a	16.0f-i	48.9c-g	16.0ab	30.6d-f	7.8a	7.9a
M0926-9	59.1bcd	62.3a-e	197.2c-e	82.4e-h	14.5j	48.2e-i	15.4bc	26.9ij	5.0gh	4.8gh
M1026-1	61.7a	64.0a	200.0b-d	80.9f-h	18.3bc	47.3hi	12.2h	35.0ab	5.4f-h	5.2f-h
M1026-11	59.1bcd	61.1d-f	207.9ab	92.9bc	16.6e-h	50.3a-c	15.6bc	27.8h-j	6.9a-c	6.7bc
M1026-13	60.3abc	63.6ab	212.0a	95.1b	18.9b	45.7jk	14.0e-g	28.2g-j	5.6e-h	5.4e-h
M1026-2	59.4a-d	62.1b-f	184.2fg	70.6j	16.2e-i	47.5g-i	15.3b-d	26.4j	5.0gh	4.8gh
M1026-3	60.2a-d	62.8a-d	211.9a	90.1b-d	19.9a	49.2c-f	13.6fg	34.4ab	7.3ab	7.1b
M1026-4	61.6a	63.9a	205.4ab	84.8d-g	20.1a	47.0ij	13.5fg	35.6a	5.7d-g	5.5d-g
M1226-2	59.1bcd	61.7c-f	187.9f	82.2e-h	16.8d-g	49.8a-d	16.5a	28.6f-i	6.5b-e	6.3b-e
M1124-17	58.8bcd	60.4f	175.4h	70.3j	16.5e-h	47.7f-i	13.3fg	32.3cd	5.3b-e	5.3f-h
M1124-24	55.9e	58.1g	185.7f	72.6ij	15.7hi	48.8c-g	13.5fg	33.1bc	6.6b-d	6.4b-d
M1124-27	58.9bcd	60.7ef	177.6gh	76.7h-j	16.4e-i	50.8a	14.5de	30.9de	6.2c-f	5.9c-f
M1124-29	59.3a-d	61.8c-f	176.3gh	78.2g-i	15.5i	48.7d-h	14.9c-e	30.2d-g	5.3f-h	5.1f-h
M1124-31	60.9abc	63.2a-c	190.4ef	91.0b-d	18.3bc	47.2hi	13.2g	29.4e-h	7.2a-c	6.9b
M1227-14	60.2a-d	63.3a-c	196.0de	94.1bc	16.0f-i	47.5g-i	14.2ef	30.8de	5.1gh	4.9gh
M1227-18	61.1ab	63.3a-c	187.0f	90.6b-d	18.5b	47.9e-i	14.2ef	30.2d-g	5.5f-h	5.4e-h
M1227-21	60.3abc	61.7c-f	189.4ef	79.7gh	16.0f-i	45.1k	14.8c-e	23.6k	4.6h	4.5h
M1227-6	59.7a-d	61.9b-f	183.2f-h	87.2c-f	15.9g-i	51.0a	16.0ab	29.0e-h	7.1a-c	6.9b
M1227-7	59.8a-d	62.0b-f	191.3ef	88.7be	16.9d-f	49.4b-e	14.1e-g	30.4d-f	6.5b-e	6.2b-e
Mean	59.7	62.0	193.6	85.7	17.0	48.3	14.4	30.3	5.9	5.8
CV	1.7	2.0	2.1	4.6	2.9	1.7	3.4	4.4	11.6	11.4

Means followed by the same letter (s) in the same column are not significantly different at P≤0.05 based on DMRT

Table 8. Mean values of ten traits for ten top-cross and ten three-way cross hybrids across three locations

Traits	Top-Cross	3-Way Cross	Mean difference	$CI_{0.95}$	CV (%)	T-value	P-value
DPOL	59.94	59.82	0.12	0.73 ± 0.97	0.17	0.29	0.78
DSLK	62.4	61.65	0.76	0.13 ± 1.38	0.86	2.39	0.02
PLHT	201.91	185.23	16.67	13.56 ± 19.77	6.09	10.65	0.00
EHT	87.71	82.83	4.81	1.34 ± 8.28	4.05	2.76	0.01
ELTH	17.4	16.59	0.82	0.28 ± 1.37	3.37	2.99	0.00
EDMT	48.38	48.39	-0.02	0.63 ± 0.59	0.01	-0.07	0.95
KROW	14.76	14.28	0.47	0.01 ± 0.96	2.34	1.95	0.04
GWT	30.29	29.99	0.29	0.89 ± 1.47	0.70	0.49	0.63
FDWT	6.25	5.93	0.32	0.03 ± 0.68	3.72	1.79	0.05
YLD	6.07	5.76	0.31	0.03 ± 0.65	3.59	1.83	0.05

Significant at 5% and 1% probability levels for t-test, CV: coefficient of variation, CI: confidence interval of mean difference, where the difference is not significant when the interval surpasses the contrast

Discussion

Multi-locational evaluation of potential hybrids prior to release is inevitable in order to avoid blunder. This evaluation is necessary for genotypes to be partially released for locations where the performance was most favourable (Ogunbodede *et al*., 2001). In this study the highly significant differences among the hybrids for grain yield and other agronomic characters evaluated might be due to the diverse backgrounds from which the hybrids used in the study were developed. This result corroborates with the findings of Ininda *et al*. (2006) and Izge and Dugje (2011). The significant genotypic effect observed for all the traits evaluated suggests potential inherent genetic diversity among the hybrids. Most of the hybrids had higher grain yield over the non-hybrid check variety (SUWAN-1SR) suggesting the superiority of the hybrids over OPVs. Superior yield potential of hybrids over OPVs have been reported by Kim *et al*. (1993) and Ajibade and Ogunbodede (2000).

The highly significant differences observed among the three locations for all the traits studied could be due to differences in the agro-ecologies of these locations. Abeokuta, Ibadan and Akure belong to derived savannah, rain forest transition and rain forest ecologies, respectively with different soil and climatic conditions. Differences due to location influence were similarly reported between Akure and Abeokuta by Fayeun *et al*. (2016) for leaf yield of fluted pumpkin and between Abeokuta and Ibadan by Oduwaye *et al*. (2013) for leaf yield of amaranthus. In this study the grain yield of the very early and short Hybrid 'M1124-24' increased with increased rainfall amount received at each location as the hybrid had highest yield in Akure and least in Abeokuta. This is in line with Izge and Dugje (2011) who reported higher grain yield among earlier flowering of three-way and top-cross hybrids. Therefore this hybrid can be recommended for high rainfall ecology. Conversely, non-hybrid check 'SUWAN1-SR' that was tall and early produced grain yield below the average. This may be attributed to high competition for assimilates between plant and ear heights and flowering. Selection for reduced growth of stems and plant height may reduce competition for assimilates at flowering and thereby decrease kernel abortion (Bănziger *et al*., 2000). Early hybrids 'M0926-7' and 'M1124-24' are likely to escape drought stress during dry-spell caused by erratic rainfall and in drought prone areas. Grain yield above 6.0 tons/ha in some of the hybrids is quite noteworthy in this study as average grain yield presently in Nigeria is put at about 1.53 tons/ha (FAO, 2013). Yield advantage among different hybrid populations has been reported by several researchers: Emygdio *et al*. (2007), Oliveira *et al*. (2012) and Teodoro *et al*. (2014) observed increased yield advantage of single cross hybrids over three-way cross hybrids by 12.27%, 13.24% and 18.59%, respectively.

The significant genotype by location interaction for grain yield and other related traits indicates that most of the hybrids performed differently at different locations because of differences in some environmental factors such as soil fertility, rainfall, relative humidity and temperature that affect growth. This is in line with the findings of Ininda *et al*. (2006) and Izge and Dugje (2011). Whereas some hybrids that showed consistent high grain yield across the three locations could be said to the stable and desirable hybrids. According to Yan and Tinker (2006), genotypes are desirable when high stability is associated with high mean performance. Thus, hybrids 'M0926-7', 'M0926-8', 'M1026-11', 'M1026-3', 'M1226-2', 'M1124-24', 'M1124-27', 'M1124-31', 'M1227-6' and 'M1227-7' are desirable.

In conclusion the effects of genotypes, locations and genotype by environment interaction were highly significant for all the traits evaluated. Majority of the hybrids had superior grain yield performance compared to the checks. The top-cross hybrids were found to be superior over the three-way cross hybrids for all the traits evaluated, except for days to 50% anthesis, ear diameter and 100-grain weight. Hybrids 'M0926-7', 'M0926-8', 'M1026-11', 'M1026-3', 'M1226-2' (top-cross hybrids), 'M1124-24', 'M1124-27', 'M1124-31', 'M1227-6' and 'M1227-7' (three-way cross hybrids) that showed highest stable yields across the three locations should be further tested in these locations to confirm their yield potential for onward release as commercial hybrids. Genotypes 'M0926-7' (top-cross hybrid) and 'M1124-24' (three-way cross hybrid) that expressed early maturity with higher grain yield would have potential benefit for maize farmers in the rainforest zones as well as in drought prone areas.

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Conflict of Interest

The authors declare that there are no conflicts of interest related to this article.

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