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Assessment of new generation of drought-tolerant maize (*Zea mays* L.) hybrids for agronomic potential and adaptation in the derived savanna agro-ecology of Nigeria

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Abstract

Development of high-yielding maize varieties that exhibit superior agronomic performance under the prevailing biotic and abiotic stress factors in the derived savanna agro-ecology of Nigeria is pivotal for confronting the menace of food shortage in the zone. Ninety-six single-cross maize hybrids and four checks were evaluated in a 10×10 triple lattice in three replications under the natural growing conditions of Ogbomoso in the rainy seasons of 2013 and 2014. Hybrids exhibited significant variation ($p < 0.0001$) for grain yield and other measured traits except for streak and *Curvularia* leaf spot. Grain yield for hybrids averaged over the two years ranged between 3,614 and 9,951 kg ha^{-1}. Each of the topmost four hybrids, namely, ADL32xEXL06, EXL01xADL36, ADL32xEXL02, and ADL32xEXL03, produced > 9,000 kg ha^{-1} which is significantly higher than the yield of the best commercial check (Oba Super 1). Grain yield was significantly and negatively correlated with northern corn leaf blight caused by *Exserohilum turcicum* (r = -0.32***) and common rust caused by *Puccinia sorghi* (r = -0.31***) though the associations were weak. Selected ten hybrids exhibited superior yield and agronomic performance, and wide adaptation to the derived savanna agro-ecological conditions.

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Introduction

The ranking of maize (*Zea mays* L.) as a cosmopolitan crop has soared in the sub-Saharan Africa (SSA) over the last few decades, having steadily displaced the traditional cereals like sorghum and millet (Kamara *et al.*, 2005). This rising profile has largely been attributed to the prolificacy of the crop (Tollenaar and Lee, 2006) and its numerous uses as food for man, feed for animals, raw material and fuel for industries (Fakorede *et al.*, 2003; Hallauer, 2007; Hao *et al.*, 2011). Maize supplies half of the calorific intakes of peoples in southern Africa, 30% in eastern Africa and 15% in West and Central Africa (Zambezi and Mwambula, 1997). A recent forecast indicated that maize will emerge as the highest producing crop particularly in the developing countries and generally in the world and that demands for maize in developing countries will double by 2050 (Pingali and Pandey, 2000; USDA, 2013).

Yields on farmers' fields in West African savanna which could be as high as 4 t ha^{-1} when conditions are optimal or as low as 1.4 t ha^{-1} when there is moisture stress (Fakorede *et al.*, 2003; Arora, 2004) are still abysmally poor. Poor yield performance on farmers' fields in Nigeria has been largely attributed to the inherently poor fertility status of the soils in the savannas and a complex of biotic and abiotic factors (Kamara *et al.*, 2013).

The derived savanna agro-ecological zone of Nigeria that lies between the guinea savannas and the humid rainforest agro-ecologies is a rapidly emerging maize cropping zone with enormous potential for producing enough maize that can support the livelihoods of resource-poor farmers particularly in south-western Nigeria (Iken and Amusa, 2004; USDA, 2010). However, similar to all other agro-ecologies in the country, the zone is now being confronted with yearly occurrences of severe drought stress which often coincide with the time of maize flowering thereby reducing yields on farmers' fields significantly (Edmeades *et al.*, 1995; Kamara *et al.*, 2005; Adebayo *et al.*, 2014). The impact of global climate change that has been predicted would intensify (Mir *et al.*, 2012) might also worsen the situation in the coming years. It has, therefore, become imperative to develop new maize varieties with drought tolerance genes in their backgrounds for the teeming maize cropping communities in the derived savanna of Nigeria.

Also, the shared condition of endemic disease infections during the raining season between the derived savanna and the humid rain forest agro-ecologies in Nigeria has necessitated that newly developed materials be assessed for response to the incidence of common cosmopolitan foliar diseases under natural inoculation (Adebayo and Menkir, 2015). Earlier works have identified foliar diseases like common rust caused by *Puccinia sorghi*, northern corn leaf blight caused by the fungus *Exserohilum turcicum* (formerly known as *Helminthosporum turcicum*), maize leaf spots caused by *Curvularia lunata*, and maize leaf streak transmitted by the leafhoppers (*Cicadulina mbila*) as important biotic factors causing significant yield reductions in maize crops in the tropical agro-ecologies (Fajemisin, 1978; Iken and Amusa, 2004; Carson *et al.*, 2004; Alakonya *et al.*, 2008; Olaoye, 2009).

Although, maize breeders select for defensive traits such as disease and pest resistance in their germplasm alongside tolerance to complex traits such as drought stress during inbred lines development, the resultant hybrids would naturally exhibit varying reactions to the incidence of the disease complex in the field (Adebayo and Menkir, 2015). Sourcing of novel alleles in introduced or exotic germplasm has been identified as a gainful breeding strategy for diversifying the genetic base of adapted materials and for raising the odds of developing superior maize hybrids (Giauffret *et al.*, 2000; Dhliwayo *et al.*, 2009; Adebayo *et al.*, 2014). However, exotic germplasm and the products obtained by combining them with adapted materials are often characterized varying degrees of adaptation in the target environment, hence the need to select stable and well-adapted genotypes (Olaoye, 2009).

It is, therefore, always necessary to evaluate such new hybrids under the prevailing natural conditions of the target environment for agronomic potential and adaptation (Olaoye, 2009; Adebayo and Menkir, 2015). The objective of this study were: (i) to evaluate a set of drought tolerant single-cross maize hybrids developed from exotic and adapted maize inbred lines for agronomic performance in the target derived savanna agro-ecology of Nigeria and (ii) to identify superior hybrids.

Materials and methods

Planting materials

Ninety-six (96) single-cross maize hybrids were developed from 24 exotic and adapted drought-tolerant inbred lines using a North Carolina Design II mating scheme for a series of studies reported in Adebayo (2012). Twelve each of the 24 lines were developed at the International Maize and Wheat Improvement Centre (CIMMYT) and the International Institute of Tropical Agriculture (IITA). Four hybrids comprising two commercial hybrid maize varieties in Nigeria (Oba Super 1 and Oba 98) and two synthetic hybrids developed at IITA using drought-tolerant germplasm (M1026-7 and M1026-8) were included to make up the 100 entries evaluated in this study (Table 1). The pedigree information of the 24 inbred lines can be found in Adebayo (2012).

Experimental site, field layout and management

The site for the two-season experiments is the Teaching and Research (T&R) Farm of Ladoke Akintola University of Technology (LAUTECH), Ogbomoso (latitude 8°10'N, longitude 4°10'E, altitude 341 m asl) located in the derived savanna agro-ecology of Nigeria. The annual mean rainfall and daily temperature of the site are 1,000-1,200 mm and 28-30°C, respectively, while the soils are alfisol which are generally low in N.

A trial composed of 100 single-cross maize hybrids including the checks was planted in the rainy seasons of 2013 and 2014. The experiment for each year was established in the last week of the month of May when the rains have become steady. Hybrids were planted using a 10×10 triple lattice design with three replications in single 5-m row plots spaced 0.75 m apart with 0.50 m spacing between plants within each row. Three seeds were sown per hill and later thinned to two plants per stand two weeks after planting (WAP) to attain a plant population density of 53,333 plants ha $^{-1}$. A compound fertilizer was applied at the rate of 60 kg N, 60 kg P, and 60 kg K per hectare at planting. An additional 60 kg ha^{-1}.N was applied in the form of urea as top dressing four weeks later. A mixture of gramoxone and primextra were applied as pre-emergence herbicides at 5.0 l ha^{-1} each of paraquat (N,N'-dimethyl-4,4-bipyridinuim dichloride) and atrazine (2-Chloro-4-ethylamino-6-isopropylamino-1,3,5-triazine). Manual weeding was subsequently done to keep the experiments weed-free.

Data collection and statistical analyses

Data were recorded on a plot basis in each year. Days to 50% anthesis (DTA) was recorded as the number of days from planting to when 50% of plants in a plot had shed pollen. Plant (PLHT) and ear (EHT) heights were measured in centimeters (cm) as the distance from the base of the plant to the height of the first tassel branch and the node bearing the upper ear, respectively. Two weeks after the completion of anthesis, plant aspect (PASP) was scored visually on a scale of 1 to 5, where 1 = excellent overall phenotypic appeal and 5 = poor overall phenotypic appeal. Ear aspect (EASP) was also visually rated on a scale of 1 to 5, where 1 = clean, uniform, large, and well-filled ears, and 5 = rotten, variable, small, and partially filled ears. Husk cover (HUSK) was scored on a scale of 1 to 5, where 1 = husks tightly arranged and extended beyond the ear tip and 5 = ear tips fully exposed. Each of the four foliar diseases namely, common rust caused by *Puccinia sorghi*, northern corn leaf blight caused by *Exserohilum turcicum*, maize leaf spots caused by *Curvularia lunata*, and maize leaf streak caused by a virus, was visually screened based on its symptom severity on a scale of 1 to 5, where 1 = no visible leaf infection and 5 = severe leaf infection (Menkir and Ayodele, 2005). All ears harvested from each plot were weighed and a representative sample from each plot was shelled to determine percent grain moisture at harvest using a moisture meter. Grain yield (kg ha^{-1}) adjusted to 15% moisture was, thus, calculated from field weight.

Separate analyses of variance (ANOVAs) were performed on the data collected in 2013 and 2014 to generate entry means adjusted for block effects according to the lattice design (Patterson *et al.* 1978). Combined analysis of variance across the two years was then computed. Replications, years and incomplete blocks were considered as random effects while experimental hybrids were considered fixed effects. All analyses were performed with PROC GLM in SAS (SAS, 2010). Pearson's correlation coefficients for all possible pairs of the measured traits computed using PROC CORR in SAS (SAS, 2010).

Results

Hybrids were analyzed over the two years according to the lattice design because the lattices have significant edge over randomized complete block design (RCBD). Year variation was significant for all measured traits except grain yield (GY), ear height (EHT), and ear aspect (EASP) (Table 2). Highly significant differences ($P < 0.0001$) were also detected among experimental hybrids for all traits except streak (STRK) and *Curvularia* leaf spot (CURV) infections (Table 2). Among the four foliar diseases, leaf rust (RUST) and northern corn leaf blight (BLT) significantly affected the performance of hybrids. Mean squares for hybrid x year interaction effects were significant for GY, days to 50% anthesis (DTA), plant height (PLHT), plant aspect (PASP), and northern corn leaf blight (BLT). Hybrids had the highest contributions to the variations observed for agronomical important traits like GY, EHT, and EASP (Table 2).

Table 1. The 96 single-cross maize hybrids and four hybrid checks evaluated during the rainy seasons of 2013 and 2014 at Teaching and Research Farm, LAUTECH, Ogbomoso in Nigeria.

Entry	*Hybrid	Entry	Hybrid	Entry	Hybrid
1	EXL01 x ADL34	35	ADL37 x EXL02	68	ADL39 x ADL27
2	EXL04 x ADL34	36	ADL38 x EXL02	69	ADL34 x ADL32
3	EXL05 x ADL34	37	ADL27 x EXL03	70	ADL35 x ADL32
4	EXL24 x ADL 34	38	ADL32 x EXL03	71	ADL36 x ADL32
5	EXL01 x ADL35	39	ADL37 x EXL03	72	ADL39 x ADL32
6	EXL04 x ADL35	40	ADL38 x EXL03	73	ADL34 x ADL37
7	EXL05 x ADL35	41	ADL27 x EXL06	74	ADL35 x ADL37
8	EXL24 x ADL35	42	ADL32 x EXL06	75	ADL36 x ADL37
9	EXL01 x ADL36	43	ADL37 x EXL06	76	ADL39 x ADL37
10	EXL04 x ADL36	44	ADL38 x EXL06	77	ADL34 x ADL38
11	EXL05 x ADL36	45	ADL27 x EXL07	78	ADL35 x ADL38
12	EXL24 x ADL36	46	ADL32 x EXL07	79	ADL36 x ADL38
13	EXL01 x ADL39	47	ADL37 x EXL07	80	ADL39 x ADL38
14	EXL04 x ADL39	48	ADL38 x EXL07	81	EXL02 x ADL31
15	EXL05 x ADL39	49	EXL10 x EXL01	82	EXL03 x ADL31
16	EXL24 x ADL39	50	EXL15 x EXL01	83	EXL06 x ADL31
17	ADL31 x EXL10	51	EXL16 x EXL01	84	EXL07 x ADL31
18	ADL41 x EXL10	52	EXL17 x EXL01	85	EXL02 x ADL41
19	ADL33 x EXL10	53	EXL10 x EXL04	86	EXL03 x ADL41
20	ADL47 x EXL10	54	EXL15 x EXL04	87	EXL06 x ADL41
21	ADL31 x EXL15	55	EXL16 x EXL04	88	EXL07 x ADL41
22	ADL41 x EXL15	56	EXL17 x EXL04	89	EXL02 x ADL33
23	ADL33 x EXL15	57	EXL10 x EXL05	90	EXL03 x ADL33
24	ADL47 x EXL15	58	EXL15 x EXL05	91	EXL06 x ADL33
25	ADL31 x EXL16	59	EXL16 x EXL05	92	EXL07 x ADL33
26	ADL41 x EXL16	60	EXL17 x EXL05	93	EXL02 x ADL47
27	ADL33 x EXL16	61	EXL10 x EXL24	94	EXL03 x ADL47
28	ADL47 x EXL16	62	EXL15 x EXL24	95	EXL06 x ADL47
29	ADL31 x EXL17	63	EXL16 x EXL24	96	EXL07 x ADL47
30	ADL41 x EXL17	64	EXL17 x EXL24	97	M1026-7 - Check
31	ADL33 x EXL17	65	ADL34 x ADL27	98	M1026-8 - Check
32	ADL47 x EXL17	66	ADL35 x ADL27	99	OBA SUPER 1 -Check
33	ADL27 x EXL02	67	ADL36 x ADL27	100	OBA 98 - Check
34	ADL32 x EXL02				

*EXL represents "exotic" maize inbred lines developed at CIMMYT; ADL represents "adapted" drought-tolerant maize inbred lines developed at IITA.

Table 2. Mean squares of traits of the 96 early generation single-cross drought-tolerant maize hybrids and four checks evaluated during the rainy seasons of 2013 and 2014 at Teaching and Research Farm, LAUTECH, Ogbomoso in Nigeria.

Source of variation	Df	[1]GY (kg ha^{-1})	DTA (d)	PLHT (cm)	EHT (cm)	HUSK (1-5)	PASP (1-5)	EASP (1-5)	STRK (1-5)	RUST (1-5)	BLT (1-5)	CURV (1-5)
Year (or Y)	1	3321559^{ns}	319.2^{***}	579^{*}	159^{ns}	1.4^{**}	21.4^{***}	0.1^{ns}	20.1^{***}	82.8^{***}	80.8^{***}	84^{*}
Rep(Y)	2	2738051^{ns}	4.9^{ns}	809^{**}	95^{ns}	1.1^{**}	0.3^{ns}	0.2^{ns}	0.1^{ns}	0.8^{**}	0.4ns	54^{ns}
Blk(Rep*Y)	36	3247901^{*}	4.2^{*}	241^{**}	140^{ns}	0.2^{ns}	0.2^{ns}	0.4^{ns}	0.1^{ns}	0.3^{*}	0.3^{**}	34^{*}
Hybrid	99	4837533^{***}	7.4^{***}	571^{***}	412^{***}	0.6^{***}	0.5^{***}	0.6^{***}	0.2^{ns}	0.4^{***}	0.6^{***}	19^{ns}
Hybrid*Y	99	3929668^{***}	3.7^{*}	193^{*}	137^{*}	0.2^{ns}	0.3^{**}	0.2^{ns}	0.1^{ns}	0.2ns	0.3^{**}	19^{ns}
Error	158	1934566	2.6	135	88	0.2	0.2	0.3	0.1	0.2	0.2	20

[1]GY=Grain yield , DTA=Days to 50% anthesis, PLHT=Plant height, EHT=Ear height, HUSK=Husk cover (1-5) where 1=husks tightly arranged and extended beyond the ear tips and 5=ear tips exposed, PASP=Plant aspect (1-5) where 1=excellent overall phenotypic appeal and 5=poor overall phenotypic appeal, EASP=Ear aspect (1-5) where 1=clean, uniform, large, and well-filled ears and 5=rotten, variable, small and partially filled ears, STRK=Streak (scale of 1-5), RUST (scale of 1-5), BLT=Blight (scale of 1-5), CUR= Curvularia (scale of 1-5).

Grain yield of hybrids in 2013 ranged between 3,772 and 9,583 kg ha^{-1} with a trial mean of 7,312 kg ha^{-1} whereas yield varied from 313 to 10,320 kg ha^{-1} with a mean of 5,453 kg ha^{-1} in 2014. Averaged over the two years, hybrids' yield ranged between 3,614 and 9,951 kg ha^{-1}, having a mean of 6,387 kg ha^{-1} (Table 3).

Table 3. Mean grain yield (GY) in kg ha^{-1} of top 10 highest yielding single-cross hybrids evaluated in Teaching and Research Farm, LAUTECH, Ogbomoso in the rainy seasons of 2013, 2014, and over the two seasons.

2013		2014		OVER 2013-2014	
*HYBRID	GY	HYBRID	GY	HYBRID	GY
ADL32 x EXL06	9583	ADL32xEXL06	10320	ADL32xEXL06	9951
EXL15 x EXL01	9540	ADL32xEXL03	9730	EXL01xADL36	9076
ADL33 x EXL15	9406	EXL01xADL36	9409	ADL32xEXL02	9063
EXL04 x ADL34	9313	ADL32xEXL02	9274	ADL32xEXL03	9058
EXL10 x EXL04	9118	EXL05xADL34	8851	EXL15xEXL04	8469
EXL05 x ADL35	8863	EXL04xADL36	8663	EXL05xADL35	8372
ADL32 x EXL02	8852	EXL15xEXL04	8574	EXL05xADL34	8258
EXL17 x EXL01	8820	EXL17xEXL05	8429	EXL15xEXL05	8211
EXL01 x ADL36	8742	EXL15xEXL05	8013	EXL16xEXL24	8110
EXL01 x ADL39	8699	EXL05xADL35	7880	EXL04xADL35	8090
Checks					
M1026-8	9273	M1026-8	7262	M1026-8	8169
M1026-7	6394	M1026-7	7065	M1026-7	6828
OBA SUPER 1	6004	OBASUPER1	7304	OBASUPER1	6654
OBA98	5925	OBA98	6583	OBA98	6254
Statistics					
Mean	*7312*	*Mean*	*5453*	*Mean*	*6387*
SE	*101*	*SE*	*168*	*SE*	*108*
$LSD_{0.05}$	*2157*	*$LSD_{0.05}$*	*2151*	*$LSD_{0.05}$*	*2125*

*EXL represents drought-tolerant maize inbred line developed at CIMMYT; ADL represents drought-tolerant maize inbred line developed at IITA.

ADL32xEXL06 was the best performing hybrid for grain yield in each of the year, and over the two years. Among the top 10 hybrids selected for their grain yield performance, three other hybrids, namely EXL05xADL35, ADL32xEXL02, and EXL01xADL36 exhibited stable performance, each producing > 8,000 kg ha^{-1} over the two seasons (Table 3). Furthermore, the top eight hybrids produced non-significantly higher grain yield than the best check (M1026-8) but the top four hybrids significantly out-yielded the best commercial check (Oba Super 1), each producing > 9,000 kg ha^{-1}, over the two years (Table 3). Among the top 10 hybrids selected for grain yield performance over the two rainy seasons, 70% are hybrids involving exotic (CIMMYT-bred) and adapted (IITA-bred) parental lines (Table 3). Days to 50% anthesis of the selected 10 hybrids varied from about 53 to 57 DAP, with the earliest hybrid maturing a day before the earliest check (M1026-7) and the latest maturing sharing the same maturity date of 57 DAP with the latest check (Table 4).

Table 4. Means of agronomic and breeder traits of top 10 highest yielding single-cross hybrids evaluated in Teaching and Research Farm, LAUTECH, Ogbomoso, over the rainy seasons of 2013 and 2014.

HYBRID	DTA	PLHT	EHT	HUSK	PASP	EASP
ADL32xEXL06	55.0	207.5	107.3	2.0	2.8	2.3
EXL01xADL36	55.5	202.0	93.8	1.9	1.9	2.9
ADL32xEXL02	54.0	190.3	105.8	2.4	2.5	3.1
ADL32xEXL03	54.0	200.0	104.3	2.3	2.6	2.1
EXL15xEXL04	55.0	191.3	89.5	2.6	2.0	2.9
EXL05xADL35	57.3	185.5	90.8	2.0	2.1	2.0
EXL05xADL34	56.3	191.8	97.3	2.4	2.3	2.6
EXL15xEXL05	55.0	193.5	96.3	2.6	2.3	2.6
EXL16xEXL24	52.8	178.0	80.3	2.5	2.5	2.4
EXL04xADL35	56.0	190.8	86.5	2.5	2.0	2.5
Checks						
M1026-8	55.0	204.8	96.0	2.8	2.8	2.8
M1026-7	54.0	214.3	95.3	2.6	2.8	3
OBASUPER1	57.3	206.3	106.8	2.0	2.6	2.6
OBA98	54.3	195.8	95.5	2.6	3.0	3.3
Statistics						
Mean	*55.1*	*188.2*	*88.5*	*88.5*	*2.6*	*2.9*
SE	*0.1*	*1.4*	*1.2*	*1.2*	*0.04*	*0.04*

DTA=Days to 50% anthesis, PLHT=Plant height, EHT=Ear height, HUSK=Husk cover (1-5) where 1=husks tightly arranged and extended beyond the ear tips and 5=ear tips exposed, PASP=Plant aspect (1-5) where 1=excellent overall phenotypic appeal and 5=poor overall phenotypic appeal, EASP=Ear aspect (1-5) where 1=clean, uniform, large, and well-filled ears and 5=rotten, variable, small and partially filled ears.

Only three of the selected 10 hybrids grew above 200 cm, thus having similar plant heights with three of the four checks. All the selected hybrids had their ears placed about the middle of their entire heights. Ratings for husk cover and the breeder traits were generally below 3.0 (Table 4).

All measured traits had significant correlations with GY except DTA and CURV, though the associations were generally weak (Table 4). The coefficients of determination (R^2) between GY and each of RUST and BLT were ≥ 10% whereas the R^2 between GY and each of PLHT and EASP was > 12% (Table 4).

Half of the selected top 10 hybrids had the same or more favorable ratings than the best commercial check (Oba 98) for RUST. Also all the top 10 hybrids had the same or more favorable ratings than the best commercial check (Oba 98) for BLT (Table 5).

Table 5. Correlation coefficients of the measured traits of the 96 single-cross hybrids and four checks evaluated during the rainy seasons of 2013 and 2014 at Teaching and Research Farm, LAUTECH, Ogbomoso in Nigeria.

	DTA	PLHT	EHT	HUSK	PASP	EASP	STRK	RUST	BLT	CURV
GY	-0.09	0.34	0.25	-0.25	-0.30	-0.35	-0.24	-0.31	-0.32	-0.06
	0.065	*<.0001*	*<.0001*	*<.000*	*<.000*	*<.000*	*<.000*	*<.000*	*<.000*	*0.27*
DTA		-0.07	0.02	0.07	0.25	0.16	0.17	0.23	0.14	-0.11
		0.174	*0.7326*	*0.182*	*<.000*	*0.001*	*0.001*	*<.000*	*0.004*	*0.03*
PLHT			0.67	-0.28	-0.25	-0.29	0.06	0.04	0.01	-0.01
			<.000	*<.000*	*<.000*	*<.000*	*0.27*	*0.40*	*0.80*	*0.97*
EHT				-0.20	-0.26	-0.26	0.07	0.06	0.04	0.06
				<.000	*<.000*	*<.000*	*0.26*	*0.24*	*0.38*	*0.27*
HUSK					0.40	0.32	0.07	0.03	-0.05	-0.09
					<.000	<.000	0.12	0.53	0.30	0.06
PASP						0.32	0.21	0.22	0.19	-0.14
						<.000	*<.000*	*<.000*	*<.000*	*0.005*
EASP							-0.02	0.02	-0.02	-0.17
							0.65	*0.68*	*0.67*	*0.001*
STRK								0.47	0.44	-0.01
								<.000	*<.000*	*0.91*
RUST									0.65	-0.04
									<.000	*0.46*
BLT										-0.09
										0.08

GY=Grain yield measured in kg ha^{-1} , DTA=Days to 50% anthesis, PLHT=Plant height in cm, EHT=Ear height in cm, HUSK=Husk cover (1-5) where 1=husks tightly arranged and extended beyond the ear tips and 5=ear tips exposed, PASP=Plant aspect (1-5) where 1=excellent overall phenotypic appeal and 5=poor overall phenotypic appeal, EASP=Ear aspect (1-5) where 1=clean, uniform, large, and well-filled ears and 5=rotten, variable, small and partially filled ears, STRK=Streak (scale of 1-5), RUST (scale of 1-5), BLT=Blight (scale of 1-5), CUR= Curvularia (scale of 1-5).

Discussion

The derived savanna agro-ecological zone, spanning slightly over 10% of the Nigeria's land area and extending southwards from the southern guinea zone into the forest zone (Adegbola and Onayinka, 1976; Iken and Amusa, 2004), has been credited with a rapidly emerging maize growing culture which requires breeding of high-yielding and well-adapted maize hybrids and other varieties. The prevalence of abundant radiation that augurs well for high maize productivity and a complex of foliar diseases that undermines quantitative and qualitative maize production in the zone have necessitated selection of superior and well-adapted genotypes from the set of new generation of single-cross maize hybrids evaluated in this study. In an earlier study, the same set of single-crosses exhibited differential response to simulated drought stress (Adebayo *et al.*, 2014) and disease infections under fully irrigated and rainfed conditions in the rainforest zone (Adebayo and Menkir, 2015). Significant genotype x environment interaction (GEI) effects recorded on the performance of the hybrids for grain yield and other important agronomic traits in three diverse agro-ecological zones (not including the derived savanna agro-ecology) in Nigeria (Adebayo, 2012) has demanded rigorous testing of the materials in every target environment in order to select superior type(s). The observed change in rank order in grain yield performance of the hybrids in the present study compared with a similar study conducted in the rainforest zone (Adebayo and Menkir, 2015) underscores the significance of GEI effects. However, the superior performance of ADL32 x EXL06 for yield and other adaptive traits in the present study and its listing among the top 10 highest yielding hybrids in similar experiments in the rainforest zone (Adebayo and Menkir, 2015) indicate its high yielding potential and wide adaptation. The mean grain yield of > 9,000 kg ha^{-1} produced by each of the top four hybrids which is significantly higher than the mean yield of the best commercial check (Oba Super 1) suggests that these hybrids are potential replacements for the existing commercial single-cross hybrid varieties, particularly in the derived savanna zone.

Table 6. Mean grain yield and mean values for the rated foliar diseases of selected top 10 single-cross hybrids evaluated over the rainy seasons of 2013 and 2014 at Teaching and Research Farm, LAUTECH, Ogbomoso in Nigeria.

HYBRID	GY (kg ha^{-1})	STRK (1-5)	RUST (1-5)	BLT (1-5)	CURV (1-5)
ADL32xEXL06	9951	1.3	2.0	2.5	2.3
EXL01xADL36	9076	1.3	2.3	2.8	1.8
ADL32xEXL02	9067	1.4	2.1	2.9	1.4
ADL32xEXL03	9058	1.4	2.6	2.6	1.3
EXL15xEXL04	8469	1.3	2.5	2.4	2.0
EXL05xADL35	8372	1.3	2.3	2.8	1.5
EXL05xADL34	8258	1.1	2.0	2.1	1.6
EXL15xEXL05	8211	2.0	2.6	2.9	2.0
EXL16xEXL24	8110	1.8	2.1	2.5	2.0
EXL04xADL35	8090	1.1	2.0	2.5	1.6
EXL04xADL34	8003	1.0	1.9	2.4	1.4
ADL33xEXL15	7912	1.6	2.8	2.8	2.3
Checks					
M1026-8	8169	1.5	1.8	1.9	1.5
M1026-7	6828	1.3	2.1	2.0	1.8
OBASUPER1	6654	1.5	2.6	3.3	2.1
OBA98	6254	1.6	2.3	2.9	1.5
Statistics					
Mean	*6387*	*1.4*	*2.4*	*2.6*	*2.0*
SE	*108*	*0.02*	*0.03*	*0.09*	*0.10*

GY=Grain yield, STRK=Streak (scale of 1-5), RUST (scale of 1-5), BLT=Blight (scale of 1-5), CUR= Curvularia (scale of 1-5).

Although, maize breeders at CIMMYT and IITA had developed adaptive and defensive traits in elite maize germplasm (Van Eijnatten, 1965; Fajemisin *et al.*, 1978; Efron *et al.*, 1989), probable evolution of new strains of the pathogens causing common foliar diseases may be posing a serious threat to high maize production and productivity in the derived savanna zone. In this study, only common rust and northern corn blight had significant impact on hybrid performance and negative associations with grain yield. This finding corroborated earlier reports that northern corn leaf blight now poses a damnable threat to maize crop in the rainforest (Adebayo and Menkir, 2015). It is imperative to screen newly developed maize hybrids under the endemic natural disease inoculation that is now prevalent in the derived savanna agro-ecology of Nigeria in order to identify and release superior ones for the use of the vibrant maize farmers in the zone.

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