PARTICIPATORY ON-FARM EVALUATION OF STRESS TOLERANT MAIZE VARIETIES AND HYBRIDS IN SOME NORTHERN STATES OF NIGERIA

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Abstract. *Maize is one of the most planted crops in Nigeria and it accounts for the largest share of the country's coarse grain production. Maize farming is carried out in nearly all the geographical zones in Nigeria. However, the bulk of the country's maize production is concentrated in Kaduna, Katsina, Niger, Plateau, Taraba, Kano and Oyo. These maize producing states accounts for nearly two-third (64%) of maize produced in Nigeria. Current maize yield averages 1.7 t/ha and is barely sufficient for the region's requirements due to drought, striga infestation and low N stresses. The objective of this study was to compare new stress tolerant maize hybrids and open pollinated varieties (OPVs) against the best released commercial varieties in Nigeria using farmer participatory approach and to validate on-station results. Maize varieties were simultaneously selected on-station from the different agro-ecology in Nigeria during the 2019/2020 and 2020/2021 seasons. During the season, 12 promising stress tolerant maize hybrids and OPVs among which are extra-early, early and intermediate were selected from the on-station based on their mean grain yield and stability. These selected varieties were compared with the best commercial check varieties on-farm across locations in Nigeria in a randomized complete block design. The genotype + genotype x environment comparison biplot showed hybrid AS1909-5, EWTH-14 together with other new stress tolerant hybrids and OPVs to be stable and high yielding on-station across locations compared to the commonly grown checks. This indicated that hybrid AS1909-5 and EWTH-14 possesses beneficial alleles that contributed to the observed superior performance when compared to the other hybrids.The new stress tolerant hybrids showed a yield advantage over the commercial check varieties both in the extra-early, early and the intermediate maturing categories, and the gains were bigger under stress conditions. Under farmers' fields, DT STR Syn/TZL Comp.-W, 2015 DTE STR-Y Syn, AS1909-5, AS2001-16, EWTH-14 and EEPVAH-95 were high yielding and stable across locations and recommended for release.*

Key words: *Stress tolerance, Grain Yield, Variety, On-farm.*

INTRODUCTION

Maize (*Zea mays* L.) is a major staple food crop in Nigeria. Its high energy content has made it very important in both human diet and animal feed. Maize is rapidly replacing traditional cereals such as sorghum (Sorghum bicolor (L.) Moench) and millet (Pennisetumglaucum (L.) R.Br.) in the guinea savannas region of Nigeria, where there is good access to fertilizer inputs and markets (BADU-APRAKU *ET AL*., 2003; KIM, J.-M. ET AL., 2012). Its ability to thrive in a wide range of soil types and many agro-ecological zones may be partly responsible for its increasing popularity over the traditional cereals of the region (MESEKA, S.K., ET AL., 2006 AND 2007). Nigeria is Africa's second largest maize producer after South Africa and the 14th largest producer globally. The total maize production in 2019 is about 11 MMT harvested from over 6.8 million hectares of land. This production level represents a growth rate of 49% relative to the production level recorded a decade earlier (FAOSTAT, 2019). However, the association of maize farmers in Nigeria gave a far higher production figure of 20 MMT in 2019 (Commodity-port.com).

Nevertheless, Nigeria's maize yield has remained relatively constant at about 1.7 t/ha since 2017. This is low compared to South Africa and Ethiopia's yield of 4.9 t/ha and 4.2 t/ha respectively. The reason for this may be due to farmers' reluctance to transit from the use of

open pollinated variety (OPV) to improved hybrid seeds as well as the high cost of these improved maize seed varieties etc. According to International Institute of Agriculture (IITA) estimates, less than 10% of Nigeria farmers uses the hybrid maize variety, which gives higher yields than the OPV largely used by farmers. The challenge of poor yield which leads to reduced maize output is exacerbated by post-harvest losses which is estimated to be about 20–30% of total maize production. Meanwhile, Nigeria's annual maize demand for human consumption and animal feed production ranges from 12–15 MMT. This puts Nigeria's maize production versus demand gap at roughly between 2–4 MMT per annum. Closing this gap requires concerted efforts by players across the value chain (KIRKHAM, M.B., ET AL., 1984).

The guinea savanna agro-ecologies of Nigeria is considered as the maize belt because a major proportion of the total maize production comes from this agro-ecology. However, the region is plagued by stresses such as low soil nitrogen, drought and Striga hermonthica (Del.) Benth, among many other stresses. These stresses causes maize yield loss ranging from 20% 95% in susceptible maize genotypes (KIM, 2012). In severe cases, total crop loss has resulted and farmers have often been compelled to abandon their farmland. Research efforts at controlling these stresses started in the early 1980s by the Maize Program unit of the International Institute of Tropical Agriculture (IITA). Control measures such as crop rotation, chemical method have been proposed, but host plant resistance and/or tolerance is considered as the most economical and environmentally friendly (PARKINSON ET AL., 1989; KIM, 2012). The low average yield of maize in the region could be attributed in large extent to poor quality seed due excessive recycling, and partly due to low cation exchange capacity (low fertility) of African soil. Other important factors responsible for low production and productivity of maize include drought, *Striga* infestation, streak virus infection and insect pests and diseases; of recent, the fall armyworm is another threat to maize production in the sub-region (MIHUT ET AL, 2019).

In order to increase maize production in Nigeria, the International Institute of Tropical Agriculture entered into an agreement with the Institute for Agricultural Research (IAR), Zaria to evaluate the performance of some of their introduced white and yellow maize varieties and hybrids in Nigeria. The purpose of the trials was to assess the performance of the varieties and hybrids maize trials in different agro-ecologies of Nigeria in order to determine their yield potential as well as their responses to prevailing disease and abiotic stress. The goal of the evaluation of the maize varieties and hybrids is to identify the promising varieties and hybrid(s) based on the multi-location and on-farm evaluation for variety registration and release in Nigeria (OYEKUNLE,M., ET AL., 2014; ROSIELLE, A. A., AND J. HAMBLIN, 1981).

Development and adoption of stress tolerant (Striga resistance, Drought tolerant, maize streak resistance, low soil nitrogen etc.,) maize varieties and hybrids will ensure suitability of maize production. IAR maize breeders have identified several early, extra-early, intermediate and late maturing white and yellow-endosperm OPVs and hybrids. Several of which combine tolerance to drought, low soil nitrogen with resistance to *S. hermonthica* and MSV. (MIHUT ET AL, 2022; MAKUMBI, D., ET AL., 2011). The goal of the study is to identify promising stress tolerant varieties and hybrids adaptable to the savanna using farmer participatory approach (MENKIR, A., ET AL., 2001). Development and adoption of stress tolerant maize varieties and hybrids will ensure suitability of maize production.

Therefore, the objectives of the present study were:

1. To conduct participatory variety evaluation through on-farm testing of stress tolerant maize varieties and hybrids in Kaduna, Katsina, Kano, Bauchi, and Jigawa States, Nigeria.

2. To use participatory approaches in helping farmers select best stress tolerant maize hybrids and varieties for adoption in the project areas with the hope of positive spill over effect to other farmers and States in the region.

MATERIALS AND METHODS

Training of extension agents and participating farmers took place at their respective communities.

On-farm evaluation of stress tolerant materials were conducted. The trials were conducted on farmers' fields to test, demonstrate and evaluate the performance of promising stress tolerant maize varieties and hybrids across Kaduna, Katsina, Kano, Bauchi and Jigawa States. Three genotypes plus farmers' variety in some cases were evaluated using 20m x 20m plot size per farmer and each farmer served as a replicate. The on-farm trials were established with 10 to 15 farmers from each state out of the two to three communities that were selected per State. 50 farmers were involved in the on-farm trials in the five States. Two to three sets of open pollinated varieties and hybrids were included, extra-early, early and intermediate/late maturing groups were evaluated. The hybrids and open-pollinated varieties tested in the on-farm trials are presented in Table 1. Three seeds per hill were planted and the seedlings were thinned to two/stand about 2 weeks after emergence to give a final plant population density of about 53,333 plants ha^{-1}. A blended fertilizer (NPK 20:10:10) was applied at the rate of 60 kg N ha^{-1}, 60 kg P ha^{-1} and 60 kg K ha^{-1} two weeks after planting (WAP) for all experiments. An additional 60 kg N ha^{-1} urea was top-dressed three weeks later. In all the trials, the field was kept weed-free through the application of a mixture of gramoxone and primextra at 5 l ha^{-1} each of gramoxone and primextra in some cases. Subsequently manual weeding was done as necessary to keep the trial fields weed-free. A total of 69 on-farm trials in the five states were conducted.

Data collection

Observation made on grain yield and other agronomic traits. Focus Group Discussions (FGDs), before and after harvest were carried out and data recorded on all aspects of the test entries.

Table 1.

Showing STMA materials evaluated in on-farm trials in northern guinea savanna of Nigeria in 2022

Type	Extra-early	Early maturing	Intermediate/late
OPVs		2013 DTE STR-Y SYN 2015 DTE STR-Y SYN	DT STR SYN/TZL Comp–1- W TZE Comp.3 DT/STR SYN
Hybrids		SAMMAZ 55	SAMMAZ 51
	EEPVAH – 95	EYQH - 54	M1124 – 12
	EEPVAH – 96	EWTH - 14	AS1909 – 5
	IFE HYBRID 6	SAMMAZ 42	AS1807 – 20
			AS2001 – 16 SAMMAZ 58 (M1628 - 3) SAMMAZ 61 (M1526 - 1)

RESULTS AND DISCUSSION

The results of all the intermediate maize OPVs across all the locations shows that DT STR Syn/TZL Comp.-1-W has the highest average grain yield per ha (4883.11kg/ha), followed by SAMMAZ 51 as shown in Table 1. DT STR Syn/TZL Comp.-1-W yielded higher across all

locations except in Malumfashi, where it yielded second after TZE Comp.3 DT/STR Syn, Table 2.

Table 2.

Grain yield and other agronomics traits of intermediate maize OPV evaluated across all locations in northern guinea savanna of Nigeria during 2022 raining season.

Enotype	Days Pollen	Days Silking	Plant Height	Ear Height	Husk Cover	Plant Aspect	Ear Aspect	Ear per Plant	Anthesis Silking Interval	Grain Yield	Fermers Ranking
DT STR Syn/TZL Comp.-1-W	60.98	62.88	187.26	88.93	1.39	1.83	1.81	1.00	1.90	4883.11	1
TZE Comp.3 DT/STR Syn	61.29	62.98	191.55	86.31	1.54	2.10	2.04	1.00	1.69	4096.87	3
SAMMAZ 51	60.64	62.55	185.60	87.74	1.50	1.94	1.99	1.00	1.90	4374.81	2
Mean	60.97	62.80	188.14	87.66	1.48	1.96	1.95	1.00	1.83	4451.60	
CV	2.02	1.93	3.23	6.20	11.35	12.20	14.19	0.00	37.61	12.65	
LSD	0.92	0.90	4.54	4.09	0.12	0.18	0.20	0.00	0.51	421.20	

Table 3.

Grain yield of intermediate maize OPV evaluated across all locations in northern guinea savanna of Nigeria during 2022 raining season.

Genotype	Gwarzo	Soba	Zaria	Agege	Bauchi	Malumfashi	Birninkudu	Across
DT STR Syn/TZL Comp-1-W	5480	2432	2233	5857	6433	4129	7618	5065
SAMMAZ 51	5051	2183	1091	5756	5652	3789	6741	4549
TZE Comp.3 DT/STR Syn	5242	1638	1451	5706	4150	4514	6338	4527
Grand Mean	**5258**	**2085**	**1451**	**5773**	**5412**	**4144**	**6899**	**4714**
LSD	**1276**	**1545**	**1116**	**2787**	**1356**	**1208**	**1025**	**592**
CV	**11**	**27**	**5**	**17**	**9**	**13**	**5**	**6**
Heritability	**0.0**	**0.1**	**0.1**	**0.0**	**0.9**	**0.3**	**0.9**	**0.8**
Genotype	**ns**	**ns**	*****	**ns**	**ns**	**ns**	**Ns**	**Ns**

The results of all the intermediate maize hybrids across all locations shows that A2001-16 has the highest average grain yield per ha (3940.81kg/ha), followed by A1807-20 with average grain yield of 3938.21kg/ha followed by AS1908-5 with average grain yield of 3847.24kg/ha across all the locations performing better than the two checks SAMMAZ 58 and SAMMAZ 61 with average grain yield of 3493.46kg/ha and 3216.53kg/ha respectively, Table 3 and Table 4.

A1807-20 yielded highest in Gwarzo and Agage with average yield of 6141kg/ha and 3973kg/ha respectively, as against Birninkudu, where the highest yield is coming from the

check SAMMAZ 61 (6330kg/ha), and Malumfashi having M1124-12 yielding highest (3423kg/ha), Table 5 and Table 6.

Table 4.

Grain yield and other agronomics traits of intermediate maize hybrid evaluated across all locations in northern guinea savanna of Nigeria during 2022 wet season.

Genotype	Days Pollen	Days Silking	Plant Height	Ear Height	Husk Cover	Plant Aspect	Ear Aspect	Ears per Plant	Anthesis Silking Interval	Grain Yield	Farmers Ranking
AS1909-5	59.36	61.47	183.89	86.25	1.53	1.96	1.89	1.00	2.11	3847.24	1
M1124-12	59.92	61.61	185.28	87.08	1.67	1.93	1.96	1.00	1.69	3348.85	3
SAMMAZ 61 (M1526-1)	58.97	60.94	181.94	87.08	1.72	1.96	1.96	1.00	1.97	3216.53	2
Mean	59.42	61.35	184.56	87.44	1.64	1.91	1.90	1.00	1.93	3442.17	
CV	1.46	1.47	3.08	5.86	15.85	10.07	12.91	0.00	23.34	15.83	
LSD	0.666	0.693	4.367	3.929	0.199	0.148	0.188	0.00	0.346	418.12	

The results of the early maize OPVs across all the locations shows that 2015 DTE STR-Y Syn yielded highest (4452.03kg/ha) followed by 2013 DTE STR-Y Syn (4310.35kg/ha). All of the two new OPVs yielded higher than the check SAMMAZ 55 which has an average yield of 3964.97kg/ha, Table 7.

SAMMAZ 55 yielded highest in Gwarzo with an average yield of 7789kg/ha where as in Soba and Zaria, the best yield comes from 2015 DTE STR-Y Syn with average yields of 3759kg/ha and 2357kg/ha respectively, but 2013 DTE STR-Y Syn yielded better across all other locations, Table 8.

The results of the early maize hybrids across all the locations shows that EWTH-14 has the highest average grain yield per ha (4452.03kg/ha), followed by EYQH-54, with average grain yield 4310.35kg/ha across all the locations as shown in Table 9.

EWTH-14 has the highest average yield in Agage (6932kg/ha) and every other locations, except in Gwarzo where EYQH-54 yielded higher (6126kg/ha), Table 10.

The results of the extra early maize hybrids across all the locations, shows that EEPVAH-95 has the highest average grain yield per ha (3870.92kg/ha), and has the best performance in Gwarzo and Agage (6026kg/ha and 4900kg/ha respectively), Table 11 and Table 12.

Table 5.

Grain yield of intermediate maize hybrid evaluated across all locations in northern guinea savanna of Nigeria during 2022 wet season.

Genotype	Days Pollen	Days Silkin	Plant Heig	Ear Heigh	Husk Cove	Plant Aspe	Ear Aspec	Ears per Plant	Anthesis Silking Interval	Grain Yield	Farme Rankin
A1807-20	59.70	61.37	184.33	88.97	1.60	1.87	2.07	1.00	1.67	3938.21	1
AS2001-16	59.97	61.93	185.83	89.67	1.50	1.93	1.87	1.00	1.97	3940.81	2
SAMMAZ 58 (M1628-3)	58.97	61.07	183.67	84.83	1.63	1.95	1.98	1.00	2.10	3493.46	3
Mean	59.54	61.46	184.61	87.82	1.58	1.92	1.96	1.000	1.91	3790.83	
CV	1.60	1.58	2.78	3.62	12.73	14.25	8.39	0	35.99	20.14	
LSD	0.79	0.805	4.3411	2.7289	0.1697	0.2218	0.1342	0	0.5756	674.65	

Table 6.

Grain yield of intermediate maize OPV evaluated across all locations in northern guinea savanna of Nigeria during 2022 raining season.

Genotype	Gwarzo	Birninkudu	Gwarzo	Malumfashi	Soba	Zaria	Across
AS1909-5	4649	5736	4649	3409	2977	2453	3842
M1124-12	3242	6068	3242	3423	2687	1939	3292
SAMMAZ 61 (M1526-1)	2683	6330	2683	3174	2646	1693	3174
Mean	**3525**	**6045**	**3525**	**3335**	**2770**	**2028**	**3436**
LSD	**1056**	**1384**	**1056**	**1848**	**1539**	**1443**	**426**
CV	**13**	**8**	**13**	**24**	**20**	**16**	**5**
Heritability	**0.9**	**0.0**	**0.9**	**0.0**	**0.0**	**0.0**	**0.9**
Genotype	**	Ns	**	ns	ns	ns	*

Table 7.

Grain yield of intermediate maize OPV evaluated across all locations in northern guinea savanna of Nigeria during 2022 raining season.

Genotype	Gwarzo	Soba	Zaria	Agege	Bauchi	Across
A1807-20	6141	2199	1857	3973	5522	4502
AS2001-16	5823	3085	1516	3270	6010	4490
SAMMAZ 58	4596	2621	2170	3097	4984	3875
Mean	**5520**	**2635**	**1848**	**3447**	**5505**	**4289**
LSD	**1747**	**410**	**345**	**2096**	**2456**	**480**
CV	**14**	**6**	**4**	**27**	**20**	**5**
Heritability	**0.7**	**1.0**	**0.0**	**0.0**	**0.0**	**0.9**
Genotype	**na**	*	**ns**	**ns**	Ns	*

Table 8.

Grain yield and other agronomic traits of early maize OPV evaluated across all locations in northern guinea savanna of Nigeria during 2022 wet season.

Genotype	Days Pollen	Days Silking	Plant Height	Ear Height	Husk Cover	Plant Aspect	Ear Aspect	Ear per Plant	Anthesis Silking Interval	Grain Yield	Farmers Ranking
2013 DTE STR-Y Syn	59.17	60.96	183.75	80.42	1.52	1.98	1.81	1.00	1.79	4310.35	1
2015 DTE STR-Y Syn	59.00	61.00	177.71	82.71	1.48	1.90	1.81	1.00	2.00	4452.03	2
SAMMAZ 55	60.00	61.79	176.46	80.00	1.46	1.88	2.17	1.00	1.79	3964.97	3
Mean	59.39	61.25	179.31	81.04	1.49	1.92	1.93	1.00	1.86	4242.45	
CV	1.66	1.36	2.78	5.31	15.70	8.37	7.31	0.00	39.84	9.82	
LSD	1.04	0.88	5.28	4.60	0.24	0.17	0.15	0.00	0.78	453.21	

Table 9.

Grain yield and other agronomic traits of early maize OPV evaluated across all locations in northern guinea savanna of Nigeria during 2022 wet season.

Genotype	Gwarzo	Soba	Zaria	Agege	Bauchi	Malumfashi	Across
2013 DTE STR-Y Syn	6273	3429	1501	6102	6936	4806	5108
2015 DTE STR-Y Syn	6376	3759	2357	4815	5608	4451	4689
SAMMAZ 55	7789	2763	1737	4309	5363	4086	4712
Mean	**6812**	**3317**	**1865**	**5076**	**5969**	**4448**	**4836**
LSD	**3065**	**1441**	**1234**	**1608**	**2387**	**1547**	**847**
CV	**20**	**16**	**12**	**14**	**14**	**15**	**8**
Heritability	**0.2**	**0.6**	**0.8**	**0.8**	**0.6**	**0.0**	**0.2**
Genotype	**ns**	**Ns**	**ns**	**ns**	**ns**	**ns**	**Ns**

Table 10.

Grain yield and other agronomics traits of early maize hybrid evaluated across five locations in northern guinea savanna of Nigeria during 2022 wet growing season.

Genotype	Days Pollen	Days Silking	Plant Height	Ear Height	Husk Cover	Plant Aspect	Ear Aspect	Ear per Plant	Anthesis Silking Interval	Grain Yield	Farmers Ranking
EYQH-54	59.17	60.96	183.75	80.42	1.52	1.98	1.81	1.00	1.79	4310.35	2
EWTH-14	59.00	61.00	177.71	82.71	1.48	1.90	1.81	1.00	2.00	4452.03	1
SAMMAZ 42	60.00	61.79	176.46	80.00	1.46	1.88	2.17	1.00	1.79	3964.97	3
Mean	53.93	61.25	179.31	81.04	1.49	1.92	1.93	1.00	1.86	4242.45	

Genotype	Days Pollen	Days Silking	Plant Height	Ear Height	Husk Cover	Plant Aspect	Ear Aspect	Ear per Plant	Anthesis Silking Interval	Grain Yield	Farmers Ranking
CV	1.66	1.36	2.78	5.31	15.70	8.37	7.31	0.00	39.84	9.82	
LSD	1.04	0.88	5.28	4.60	0.24	0.17	0.15	0.00	0.78	453.21	

Table 11.

Grain yield of early maize hybrids evaluated across four locations in northern guinea savanna of Nigeria during 2022 wet growing season.

Genotype	Gwarzo	Soba	Zaria	Agege	Across
EYQH-54	6126	2273	2533	6310	5070
EWTH-14	5864	2393	2620	6932	5270
SAMMAZ 42	4820	3205	3191	4644	4485
Mean	**5603**	**2624**	**2781**	**5962**	**4941**
LSD	**1340**	**1338**	**1360**	**1420**	**713**
CV	**11**	**18**	**10**	**14**	**6**
Heritability	**0.8**	**0.6**	**0.9**	**0.7**	**0.8**
Genotype	**ns**	**ns**	**ns**	*****	**ns**

Table 12.

Grain yield of extra early maize hybrids evaluated across four locations in northern guinea savanna of Nigeria during 2022 wet growing season.

Genotype	Days Pollen	Days Silking	Plant Height	Ear Height	Husk Cover	Plant Aspect	Ear Aspect	Ear per Plant	Anthesis Silking Interval	Grain Yield	Farmers Ranking
EEPVAH-95	58.08	58.63	172.50	71.88	1.48	1.90	1.88	1.00	1.54	3870.92	1
EEPVAH-96	57.58	59.00	178.96	75.63	1.42	1.88	1.81	1.00	1.92	3735.64	2
IFE-HYB (	58.13	59.71	175.42	77.08	1.67	1.98	2.02	1.00	1.83	3441.59	3
Mean	57.93	59.11	175.63	74.86	1.52	1.92	1.90	1.00	1.76	3682.72	
CV	0.79	0.89	1.97	8.75	6.09	10.91	10.16	0.00	53.55	4.88	
LSD	0.48	0.55	3.71	7.20	0.10	0.21	0.20	0.00	1.02	199.21	

Table 13.

Grain yield of extra early maize hybrids evaluated across four locations in northern guinea savanna of Nigeria during 2022 wet growing season.

Genotype	Gwarzo	Soba	Zaria	Agage	Across
EEPVA H-95	6026	2964	1594	4900	4525
EEPVA H-96	5272	3553	2202	3915	4121
IFE-HYB 6	5169	2524	2068	4005	3916
Grand Mean	**5489**	**3014**	**1955**	**4273**	**4187**
LSD	**620**	**484**	**836**	**1534**	**634**
CV	**5**	**6**	**5**	**8**	**7**
Heritability	**0.9**	**1.0**	**0.1**	**0.6**	**0.7**
Genotype	*	*	*	ns	ns

CONCLUSIONS

Results of the combined analysis across locations allowed identification of high yielding varieties and hybrids with stable performance across all the locations. Based on the performances of some of these varieties and hybrids across all locations such as the intermediate hybrid (AS1909-5and AS2001-16), intermediate OPV (DT STR Syn/TZL Comp-1-W), early OPV (2015 DTE STR-Y Syn), early hybrid (EWTH-14) and extra early hybrid (EEPVAH-95) in the overall on-farm trials, thus, these varieties and hybrids are therefore, recommended for release and registration in Nigeria. These should also be promoted for commercialization and adoption in order to address the challenges facing maize production in Sub-Saharan African agriculture such as the emerging threats from biotic and abiotic factors due to climate change.

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