# Evaluation of multi-stress tolerant maize varieties for sustainable intensification in Northern Guinea Savanna of north eastern Nigeria

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## Abstract

Maize productivity is limited by multiple stresses in the savannas of West and Central Africa. Field trials were conducted in northern Guinea savanna of Nigeria in 2011 and 2012 to evaluate the performance of multi-stress tolerant maize varieties. Thirteen varieties including Local Check replicated three times were tested in randomized complete block design. Plant and ear heights were significantly higher for LNTP x LNP-WC3 and 2004 TZE-W DT-STRC4 than POOL 18-SR, 2009 TZE-W POP-STR, EVDT 99-W STR; and EVDT 2000-Y STRQPM, respectively. Striga count was significantly lower for EVDT 99-W STR and LNTP x LNP-WC3 than all the other entries. Days to 50% tassel and 50% silk were each significantly earlier for EVDT 99STR W-STR QPM, DT-W STR SYN, EVDT-99W STR and 2009 TZEW DT STR than the Local Check. Anthesis Silk Interval (ASI) was significantly lower for TZE COMP3 DT-WC2, 2009 TZEW DT STR, and EVDT 99-W STR than Local Check. Number of ears plant$^{-1}$ was significantly higher for 2008 DTMA-Y STR than Local Check. Grain yield ha$^{-1}$ was significantly superior for DT-Y STR SYN, 2008 DTMA-Y STR, 2004 TZE-W DTSTR C4, 2009 TZEW DT STR and EVDT 99-W STRQPM, respectively. Plant height was positively correlated with ASI and ear height, while ear height was positively associated with ears plant$^{-1}$, days to 50% silk and 50% tassel. Grain yield ha$^{-1}$ was positively correlated with ears plant$^{-1}$, days to 50 % silk, days to 50% tassel and ear height, while ears plant$^{-1}$ was negatively correlated with ear weight. Farmer selection criteria for acceptance of variety were in the order: Striga tolerance > nutrient value > drought tolerance > flour value > good taste > high yield > early maturity. The five varieties: DTY STR SYN, 2008 DTMA-Y STR, 2004 TZE-W DT STRC4, 2009 TZEW DT STR and EVDT 99-W STRQPM satisfied farmers criteria and were promising and thus nominated for on-farm demonstration and subsequent adoption in the region.

**Keywords**: maize variety, multi stress tolerant, farmer criteria, guinea savanna, Nigeria

## Introduction

Maize (*Zea mays* L) is the third most important cereal crop in the World after rice and wheat. It is the major staple food for more than 1.2 billion people in Africa and Latin America (FAOSTAT, 2013). Maize is produced primarily for human consumption either as fresh or processed product. In addition, maize is produced for animal feed and industrial uses such as starch, flour, ethanol, cooking syrup and crisp (Izge et al, 2009). According to FAOSTAT (2013) a total of 885.3 million metric tons of maize was realized worldwide from 171.8 million hectares in 2011. Out of this total, Africa contributed 65.7 million metric tons or 7.4 % from 34.6 million hectares while Nigeria realized 9.2 million metric tons or about 1.03% of the world total from 6 million hectares. The average grain yield per unit area was 5.2 tons ha$^{-1}$ for the World total, 1.9 tons ha$^{-1}$ for Africa and 1.5 tons ha$^{-1}$ for Nigeria in 2011 (FAOSTAT, 2013). Thus maize grain yield per unit area in Nigeria is less than 30% of the World average

Historical trends have suggested that the major factor responsible for increase in maize production in Nigeria is expansion in land under its cultivation rather than an improvement in yields per unit area. The total land area under maize cultivation in Nigeria has been on a steady increase from 0.65 million hectares in 1984, 4.5 million hectares in 2004 and 6 million ha in 2011 (FAOSTAT, 2013). Currently, Nigeria's yield per hectare remains lower than the world average of the 1960's (1.9 tons ha$^{-1}$). It ranged between 1.63 and 1.76 tons ha$^{-1}$ between 2004 and 2007, much lower than the world average which has ranged between 4.88 and 4.93 tons ha$^{-1}$ for the same period (USDA, 2008).The major reasons advanced for this trend are farmers use of unscientific production practices, decline in soil fertility, bush burning; intensive cropping, overgrazing and soil erosion (Law-Ogbomo and Remison, 2008). Other reasons advanced for the low yield are low use of fertilizers, herbicides and improved seeds, unreliable and erratic rainfall sometimes resulting in drought (Fakorede et al, 2001).

The savanna soils in Nigeria are low in organic matter and available Nitrogen and hence reduc-

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ing maize yield by as much as 40% (Baenziger and Lafitte, 1997). However, as a result of high cost of N fertilizer, poor distribution system and low purchasing power (Fakorede et al, 2001), farmers apply an average of 13 kg $ha^{-1}$ as against the world average of 100 kg/ha or FAO recommendation of 200 kg $ha^{-1}$ (Omonona, 2013). Drought can result in grain yield reduction by as much as 90% when it occurs from a few days before tassel emergence to the beginning of grain filling (NeSmith and Ritchie, 1992). The risk of drought stress is especially high in Sudan savanna where rainfall is unreliable and its distribution is erratic. Grain yield losses from Striga infestation of maize fields can range from 10-100% depending on the number of stress factors that affect the crop simultaneously (Oswald and Ransom, 2001). These multiple stress factors often occur simultaneously and results in the abysmal low grain yield that is more common at the farmer level. Drought and low nutrient status aggravates Striga parasitism on maize, but grain yield reduction in plots with both Striga and drought stress ranged between 56 and 77% when compared with yield reduction from Striga alone (Kim and Adetimirin, 1997).

Efforts in maize improvement for grain yield potential and stability in Nigeria have advanced over the years since 1950. Maize breeding efforts which began with the introgression of genes for pest and disease resistance (Fakorede et al, 2001) to the development of maize genotypes (open pollinated varieties and hybrids) with high grain yield potential as well as adaptation to different ecologies and stress factors (Kim, 1997) such as *Striga hermonthica* (Del) Benth, and drought, have resulted in the development and release of productive maize varieties for different agro-ecologies in Nigeria. Kamara et al (2004) reported genetic gain in grain yield of 0.41% $year^{-1}$ in open pollinated maize varieties developed for West and Central Africa between 1970 and 1999 across the West African savannas.

However, it is critical to select a suitable environment that optimizes genetic gain both within and across environments (Zavala-Garcia et al, 1992). New maize varieties that are resistant or tolerant to multiple biotic and abiotic stresses developed from diverse sources of germplasm are being assessed for environmental adaptability, grain yield stability and farmer acceptability. These new varieties could surpass the performance of those previously released or commonly grown among the farmers in the region. Modern cultivars have been improved for various biotic and abiotic stresses such as drought, waterlogged soils, N deficiency, root lodging, pre-mature death, stalk rot, insects and barrenness (Duvick, 1997). A large fraction of yield improvement in maize may be ascribed to the ability of newer cultivars to better tolerate stress conditions, like night temperature during the grain filling period, soil moisture and weed interference (Fanadzo et al, 2007).

Although the performance of the new maize varieties could be high under the controlled on station research level of the Research Institutes, there is need to test these varieties across the farmer ecologies in Nigeria. This is because maize grain yield could differ across ecologies depending on the adaptation of the varieties to weather, stress factors and soil conditions prevalent across the diverse ecologies. In other words, the performance of a variety could be location specific. Multi-stress tolerant maize varieties may provide the panacea for reducing the multiple maize production constraints farmers are grappling with at the farm level.

A key link in Agricultural Research for Development effort is the search for solutions to farmer production constrains identified during field diagnosis. The key factors that constrain farmers' adoption of technologies are inappropriateness of the technologies, unavailability of required inputs and farmers' socio-economic conditions (KARI, 1996). Technologies that do not meet farmers' preferences, objectives and conditions are less likely to be adopted. Farmer evaluations help scientists to design, test and recommend new technologies in light of information about farmers' criteria for usefulness of the innovation (Ashby, 1991). The present study was an effort towards identifying maize varieties that are tolerant to low soil fertility, drought and Striga being the major constraints limiting maize productivity in the study area. The mother - baby trial is a research process to raise awareness and encourage farmers to test basket of technology options applicable to their environment (Ellis-Jones et al, 2004). The design aims to bridge the gap between breeders and farmers and also ensure that new varieties satisfy farmers' preferences and suit their socioeconomic situation (Baenziger and de Meyer, 2000). This article reports the results of mother trial established to assess the performance of new maize varieties that are multi-stress tolerant in a farmer environment. The specific objectives were to: i) determine the performance of the multi-stress tolerant maize varieties in the farm environment; ii) determine farmer selection criteria for variety adoption; iii) identify varieties for nomination for on-farm demonstration and subsequent adoption.

## Materials and Methods

Field experiments were conducted at Askira research station (Latitude 10°38.24'N, and Longitude 12°55.04'E, 472 m above sea level) in northern Guinea savanna of northeastern Nigeria during 2011 and 2012 rainy seasons. Average annual rainfall is about 1,000 mm and the length of the rainy season is about 130 days occurring between late May and early October. There is little variation in the pattern of wind orientation between the months of November and April while between June and October, the wind direction changes and rain bearing winds blow mainly from the southeast. The maximum temperature is about 40°C

Table 1 - Characteristics of the early maturing maize varieties evaluated.

| S/No. | Variety | Characteristics |
|---|---|---|
| 1 | POOL 18 SR/AKS 94 DMRESRW | Drought tolerant, Downey mildew and streak resistant, white grain |
| 2 | 2004 TZE W DT STRC4 | Drought tolerant, Striga tolerant, white grain |
| 3 | EVDT 99 W STR QPM | Drought tolerant, Striga tolerant, quality protein maize, white grain |
| 4 | DT Y STR SYN | Drought tolerant, Striga tolerant, yellow grain |
| 5 | 2008 DTMA Y STR | Drought tolerant, Striga tolerant, yellow grain |
| 6 | DT W STR SYN | Drought tolerant, Striga tolerant, white grain |
| 7 | EVDT 2000 Y STR QPM | Drought tolerant, Striga tolerant, quality protein maize, yellow grain |
| 8 | TZE COMP3 DT WC2 | Drought tolerant, white grain |
| 9 | EVDT 99 W STR | Drought tolerant, Striga tolerant, white grain |
| 10 | LNTP x LNP W C3 | Low nitrogen tolerant pool, white grain |
| 11 | ACR. 94TZE W POP STR | Striga tolerant, white grain |
| 12 | 2009 TZEW DT STR | Drought tolerant, Striga tolerant, white grain |

especially in April while minimum is about 18°C between December and January.

Analysis of the surface soil (0-15 cm) at the experimental site prior to establishment showed that the texture was sandy loam comprising 75.5, 15.0 and 9.5% sand, silt and clay, respectively. The soil reaction was slightly acidic (6.21) and electrical conductivity (EC) was generally low (< 0.40 d $Sm^{-1}$). Organic carbon was also low (< 10 g $kg^{-1}$) while total nitrogen was moderate (1.7 g $kg^{-1}$). Available phosphorus was low (3.00 mg $kg^{-1}$) and exchangeable potassium was moderate (0.40 $Cmol^{+}$ $kg^{-1}$). Exchangeable calcium was also moderate (5.40 $Cmol^{+}$ $kg^{-1}$) while exchangeable magnesium was high (4.70 $Cmol^{+}$ $kg^{-1}$). The soil is classified as Ustalfs according to USDA soil taxonomy.

The rains started as early as May during the two years. However, the rains did not establish until second week of July. The distribution was erratic and the events were few before establishment. There were beginning of season drought for three weeks in 2011 and two weeks in 2012, which delayed crop establishment. Although floods were observed in August in 2012, about 10 days end of season drought was observed between September and October. The study was conducted under natural rainfall and farmer environment.

Twelve improved maize varieties representing 15 years (1994 to 2009) of breeding efforts were sourced from the International Institute of Tropical Agriculture (IITA) Ibadan (Table 1) and one local check was selected for the experiment. Randomized Complete Block Design was used to evaluate the 13 varieties which were replicated three times. Each variety was grown in a plot comprising 4 rows each 5 meters long.

Maize was sown after land preparation with ox-drawn plough at 75 cm x 40 cm on 22$^{nd}$ and 21$^{st}$ July 2011 and 2012, respectively. Maize seedlings were thinned to two plants $stand^{-1}$ at two weeks after sowing (WAS). Recommended fertilizer rate of 100:50:50 (Onyibe et al, 2006) was applied in 2 split doses. The first dose of 50:50:50 was applied 10 days after sowing using NPK (15:15:15) by dibbling 8 to 10 cm away from the stand. The second dose of 50 kg N $ha^{-1}$ was also applied by side dibbling 15 cm away from the stand at four WAS. Weeds were removed manually at two and four WAS using the African hand hoe. Maize stands were earthen up at four WAS during second weeding. These operations were repeated during the two years of the experiment. All plots were harvested in November each year.

Farmer field days were organized on 2$^{nd}$ November 2011 and 20$^{th}$ October 2012 to showcase the performance of the varieties and ginger farmer response for variety selection. A total of 112 persons (72 males and 40 females) including farmers and community leaders drawn from 4 communities participated during the field day in 2011, while 154 persons comprising 82 males and 72 females participated in 2012. Farmer representatives went round and inspected the performance of the varieties in each plot. The Farmers outlined their selection criteria for a maize variety. Pair-wise ranking of the selection criteria was made by the farmers in 2012 to determine their ranking.

Growth and development parameters such as plant and ear heights were measured at harvest. Number of days to 50% tassel and 50% silk, anthesis- silk interval (ASI); and yield parameters such as number of ears $plant^{-1}$, single ear weight and grain yield $ha^{-1}$ were collected. Striga counts were made from 1.0 $m^2$ quadrat randomly chosen from 5 places in each plot at 10 WAS. Grain yield was taken from a net plot of two central rows leaving the two outer rows and four outer hills as discard. Data collected were subjected to ANOVA F-test using Statistix Analytical Software (Statistix, 2005). Treatment means were compared using Duncan Multiple Range Test (DMRT) at 5% level of probability. Linear correlation was calculated to determine the degree of association among agronomic parameters measured.

## Results and Discussion

The performance of the maize varieties showed that plant height was significantly higher for LNTP x LNP W C3 and 2004 TZE-W DT STRC4 than EVDT 99-W STR and 2009 TZEW DT STR (Table 2). There was no significant difference among the other varieties including the Local Check. A similar trend was

Table 2 - Effect of maize varieties on plant height, ear height, and Striga count per m².

| Variety | Plant height (cm) | | | Ear height (cm) | | | Striga count $m^{-2}$ | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2011 | 2012 | Combined | 2011 | 2012 | Combined | 2011 | 2012 | Combined |
| Pool 18 SR/AKS 94 | 160.0 bcd | 157.7 bc | 158.8 bcd | 62.0 abc | 49.0 c | 55.5 d | 0.75 a | 0.72 a | 0.73 ab |
| 2004TZEWDTSTRC4 | 170.0 a | 168.7 a-c | 169.3 a | 68.7 ab | 65.0 a | 66.8 a | 0.85 a | 0.75 a | 0.80 ab |
| EVDT99WSTRQPM | 166.7 a-c | 165.7 a-c | 166.2 ab | 66.3 a-c | 64.3 a | 65.3 a | 0.79 a | 0.72 a | 0.75 ab |
| DTYSTRSYN | 163.3 a-d | 164.3 a-c | 163.8 a-d | 67.7 a-c | 59.7 ab | 63.7 a-c | 0.75 a | 0.72 a | 0.73 ab |
| 2008DTMAYSTR | 169.3 ab | 162.3 a-c | 165.8 a-c | 69.7 ab | 59.0 ab | 64.3 ab | 0.83 a | 0.73 a | 0.77 ab |
| DTWSTRSYN | 167.0 a-c | 165.3 a-c | 166.2 ab | 60.3 bc | 62.0 a | 61.2 a-d | 0.71 a | 0.71 a | 0.71 b |
| EVDT2000YSTRQPM | 164.3 a-d | 159.0 bc | 161.7 a-d | 62.0 a-c | 53.0 bc | 57.5 cd | 0.82 a | 0.73 a | 0.77 ab |
| TZECOMP3DTWC2 | 159.0 cd | 166.7 a-c | 162.8 a-d | 60.0 bc | 57.7 ab | 58.8 b-d | 0.95 a | 0.73 a | 0.83 a |
| EVDT99WSTR | 156.7 d | 156.7 bc | 156.7 d | 58.0 c | 56.7 abc | 57.3 cd | 0.71 a | 0.71 a | 0.71 b |
| LNTP x LNP W C3 | 170.3 a | 166.0 a-c | 168.2 a | 70.7 a | 59.7 ab | 65.2 ab | 0.71 a | 0.71 a | 0.71 b |
| ACR94TZEWPOPSTR | 165.0 a-d | 169.7 ab | 167.3 ab | 66.0 a-c | 62.0 a | 64.0 ab | 0.75 a | 0.72 a | 0.73 ab |
| 2009TZEWDTSTR | 161.0 a-d | 153.7 c | 157.3 cd | 63.7 a-c | 51.3 bc | 57.5 cd | 0.86 a | 0.73 a | 0.79 ab |
| LOCAL CHECK | 161.7 a-d | 177.3 a | 169.5 a | 62.0 a-c | 63.3 a | 62.7 a-c | 0.79 a | 0.73 a | 0.76 ab |
| SE | 4.68 | 7.62 | 4.39 | 4.87 | 4.12 | 3.22 | 0.115 | 0.019 | 0.057 |

Means followed by the same letter (s) in a column are not significantly different at 5% level of probability, according to Duncan Multiple Range Test (DMRT). Values for Striga counts are square root transformation √ y + 0.5, where y = Striga count. Values of 0.71 indicate no Striga plant observed.

observed in ear height where LNTP x LNP WC3 had significantly higher ear height during the first year, while 2004 TZEW DT STR C4 and EVDT 99 W STR QPM significantly produced superior ear height during the second year and across the years. The varieties EVDT 99-W STR, 2009 TZEW DT STR and EVDT 2000-Y STR QPM significantly produced the shortest ear height.

The expression of plant and ear heights depends on the variety and the environment. Plant and ear heights are among the growth characters for Distinctiveness, Uniformity and Stability (DUS) of a variety. Apart from the inherent genetic ability, several environmental and agronomic factors such as plant density, fertilization, pests and diseases influence the expression of these characters. LNTP x LNP WC3 being a low nitrogen tolerant variety realized taller plants and exhibited favorable response to the environmental conditions. Baenziger et al (1999) demonstrated that improvement for drought tolerance also resulted in specific adaptation and improved performance under low nitrogen. However, the realization of superior vegetative growth does not automatically result in superior grain yield. This is because the translocation rate of assimilates to the kernels of shorter hybrids was found to be greater than that of taller ones (Begna et al, 2000). Also, short plant or ear height is a positive attribute as it prevents root lodging.

Striga population did not significantly differ among the varieties (Table 2). However, TZE COMP 3DT WC2 significantly promoted more Striga population than LNTP x LNP WC3, DT-W STR SYN and EVDT 99 W STR across the years. The variety TZE COMP 3 DT WC2 probably supports more Striga plants. The Striga population was relatively low during the period of the study probably due to the moderate level of soil N and the inherent tolerance/resistance .expressed by the varieties tested. No Striga plants were observed under DT-W STR SYN, EVDT 99-W STR and LNTP x LNP WC3 as shown by the transformed values (Table 2). These varieties combine Striga tolerance with drought or low nitrogen tolerance which could reduce Striga emergence more. Badu-Apraku et al (2004) reported that use of varieties resistant or tolerant to Striga is considered the most economically feasible and sustainable approach for reducing Striga damage to maize in the savanna region of Africa. The Striga counts had no significant effect on grain yield probably due to the level of tolerance/resistance inherent in the varieties or due to their low population or both. Maize yields are usually much more closely related to Striga damage symptoms than to Striga

Table 3 - Effect of maize varieties on number of days to 50% tassel, 50% silk and anthesis – Silk interval (ASI).

| Variety | Days 50% tassel | | | Days to 50% silk | | | ASI | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2011 | 2012 | Combined | 2011 | 2012 | Combined | 2011 | 2012 | Combined |
| Pool 18 SR/AKS 94 | 57.0 ab | 43.3 e | 50.2b c | 60.7 abc | 46.3 e | 53.5 bc | 3.7 ab | 3.0 cd | 3.3 bc |
| 2004TZEWDTSTRC4 | 53.7 ab | 48.7 b | 51.2b c | 56.7 bc | 53.7 b | 55.2 bc | 3.0 b | 5.0 ab | 4.0 bc |
| EVDT99WSTRQPM | 52.0 b | 47.0 bcd | 49.5b c | 57.3 bc | 51.7 bcd | 54.5 bc | 5.0 a | 4.7 abc | 4.8 a |
| DTYSTRSYN | 54.0 ab | 48.0 bc | 51.0b c | 57.3 bc | 52.0 bc | 54.7 bc | 3.3 ab | 4.0 a-d | 3.7 bc |
| 2008DTMAYSTR | 57.0 ab | 43.7 e | 50.3b c | 60.3 abc | 47.0 e | 53.7 bc | 3.3 ab | 3.3 b-d | 3.3 bc |
| DTWSTRSYN | 52.3 b | 44.3 de | 48.3 c | 55.7 bc | 48.0 de | 51.8 c | 3.3 ab | 3.7 a-d | 3.5 bc |
| EVDT2000YSTRQPM | 52.3 b | 44.7 de | 48.5 c | 56.0 bc | 48.0 de | 52.0 bc | 3.7 ab | 3.3 b-d | 3.5 bc |
| TZECOMP3DTWC2 | 55.3 ab | 45.7 cde | 50.5 bc | 57.7 abc | 49.3 c-e | 53.5 bc | 2.3 b | 3.7 a-d | 3.0 c |
| EVDT99WSTR | 52.3 b | 44.7 de | 48.5 c | 55.3 c | 47.7 e | 51.5 c | 3.0 b | 3.0 cd | 3.0 c |
| LNTP x LNP W C3 | 60.0 a | 44.3 de | 52.2 b | 64.0 a | 47.3 e | 55.7 b | 4.0 ab | 3.0 cd | 3.5 bc |
| ACR94TZEWPOPSTR | 57.0 ab | 44.3 de | 50.7 bc | 62.0 ab | 47.7 e | 54.8 bc | 5.0 a | 3.3 b-d | 4.2 a-c |
| 2009TZEWDTSTR | 53.7 ab | 44.3 de | 49.0 bc | 56.3 bc | 47.0 e | 51.7 c | 4.0 ab | 2.7 d | 3.3 bc |
| LOCAL CHECK | 53.3 ab | 59.3 a | 56.3 a | 56.7 bc | 64.7 a | 60.7 a | 3.3 ab | 5.3 a | 4.3 ab |
| SE | 3.25 | 1.356 | 1.756 | 3.20 | 1.90 | 1.858 | 0.92 | 0.916 | 0.639 |

Means followed by the same letter (s) in a column are not significantly different at 5% level of probability, according to Duncan Multiple Range Test (DMRT).

plant numbers.

The period to flowering and silking significantly differed among the maize varieties (Table 3). Number of days to 50% tassel was significantly delayed for LNTP x LNP WC3 and the Local Check than EVDT 99 W STR QPM, DT W STR SYN, EVDT 2000 Y STR QPM and EVDT 99 W STR. The two varieties: DTW STR SYN and EVDT 2000 Y STR QPM had slightly the lowest number of days to tassel indicating early period to flowering. Similarly, days to 50% silk was significantly delayed for the Local Check than the improved maize varieties (Table 3). Days to silk were significantly delayed for LNTP x LNP WC3 than DTW STR SYN, EVDT 99 W STR and 2009 TZEW DT STR that had the earliest period to silk. The Local Check and LNTP x LNP WC3 apparently flowered and matured latter than the other varieties. Herrero and Johnson (1981) reported that delay in silk emergence results in a decreased kernel number, which in turn results in lower grain yield

The Anthesis - Silk Interval (ASI) was significantly lower for TZE COMP3 DT WC2, 2004 TZE W DT STRC4 and EVDT 99 W STR than EVDT 99 W STR QPM and ACR94 TZE W POP STR in 2011 (Table 3). The Local Check had significantly higher ASI in 2012 which was comparable to 2004 TZE W DT STRC4, EVDT 99 STR QPM, and DT Y STR SYN. Results for the combined mean showed significantly higher ASI for EVDT 99 W STR QPM which was comparable to the Local Check and ACR94 TZE W POP STR. The shortest values of ASI were observed for TZE COMP3 DT WC2, EVDT 99 W STR, 2009 TZEW DT STR and 2008 DTMA Y STR, respectively. The short period between tasselling and silking of these varieties indicate high traits for drought tolerance. Baenziger et al (1999) concluded that a variety with shorter ASI, the presence of stay green trait, increased ears per plant and increased biomass under drought are associated with high grain yield. A reduced ASI is a symptom of increased partitioning of assimilates to ears around flowering time enabling stress tolerant genotypes to reach silk earlier and to have greater ear biomass at anthesis. An asynchronous flowering can limit grain production due to lack of pollen, loss of silk receptivity or early kernel abortion (Carcovas and Otegui, 2001).

The measure of prolificacy among the maize varieties was determined by the number of ears produced per plant. Number of ears plant$^{-1}$ was significantly lower for the Local Check, Pool 18 SR, EVDT 2000 Y STR QPM, and EVDT 99 W STR QPM than the other improved varieties (Table 4). Significantly higher number of ears was observed for DTY STR SYN, EVDT 99 W STR, DT W STR SYN and 2004 TZE W DT STRC4, respectively. The variety 2008 DTMA Y STR significantly realized higher number of ears per plant across the years. The number of ears per plant of 2008 DTMA Y STR (1.62 ears plant$^{-1}$) and DTYSTR SYN (1.56 ears plant$^{-1}$) was almost double that of the Local Check (0.84 ears plant$^{-1}$) across the two years (Table 4). The Local Check, EVDT 2000 Y STR QPM and TZE COMP 3 DT WC2 significantly produced the lowest number of ears plant$^{-1}$ and thus were the least prolific among the varieties tested. The level of prolificacy has direct bearing on grain yield. Yield increases in improved strains of maize are usually associated with increased prolificacy. Durieux et al (1993) found that the yield per ear of non-prolific hybrid was higher .than that of the prolific hybrid, but that, the total yield per plant of the prolific hybrid was higher because of the formation of a second ear.

Ear weight of the maize varieties significantly differed in 2012 and across the two years (Table 4). There was no significant difference in 2011. The Local Check significantly produced heavier ears than 2009 TZEW DT STR for the combined mean. The improved varieties that slightly realized heavier cobs were EVDT 2000 Y STR QPM, EVDT 99 W STR QPM, TZE COMP 3DT WC2 and ACR 94 TZEW POP STR, respectively. It is apparent that most of the improved varieties that were prolific compromised ear weight probably due to the interplay of genotype and intra-plant competition.

Grain yield per ha was significantly superior for DT Y STR SYN, 2008 DTMA Y STR, and EVDT 99 W STR QPM across the years (Table 4). The three vari-

Table 4 - Effect of maize varieties on number of ears per plant, ear weight (g) and grain yield (kg ha$^{-1}$).

| Variety | Ears plant$^{-1}$ | | | Ear weight (g) | | | Grain yield (kg ha$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2011 | 2012 | Combined | 2011 | 2012 | Combined | 2011 | 2012 | Combined |
| Pool 18 SR/AKS 94 | 1.05 bc | 1.55 ab | 1.30 cd | 92.0 a | 76.0 e | 84.0 b | 1,711.1 cd | 1,583.3 c | 1,647.2 de |
| 2004TZEWDTSTRC4 | 1.52 a | 1.51 ab | 1.51 a-c | 86.0 a | 79.7 de | 82.8 ab | 2,966.5 ab | 2,972.2 a | 2,969.4 ab |
| EVDT99WSTRQPM | 1.10 bc | 1.30 a-c | 1.20 d | 97.7 a | 92.0 cd | 93.8 ab | 2,688.8 ab | 2,944.4 a | 2,816.6 ab |
| DTYSTRSYN | 1.58 a | 1.55 ab | 1.56 ab | 91.0 a | 81.0 c-e | 86.0 ab | 3,299.9 a | 3,138.9 a | 3,219.4 a |
| 2008DTMAYSTR | 1.45 a | 1.78 a | 1.62 a | 88.3 a | 79.7 de | 84.0 ab | 3,344.3 a | 2,972.2 a | 3,158.3 a |
| DTWSTRSYN | 1.55 a | 1.17 b-d | 1.36 a-d | 77.7 a | 85.3 b-e | 81.5 ab | 2,711.1 ab | 1,666.7 c | 2,188.9 cd |
| EVDT2000YSTRQPM | 1.09 bc | 1.12 b-d | 1.11 de | 93.0 a | 95.0 bc | 94.0 ab | 2,377.7 bc | 1,750.0 c | 2,063.9 cd |
| TZECOMP3DTWC2 | 1.32 a-c | 0.91 cd | 1.11 de | 83.7 a | 95.7 b | 89.7 ab | 2,733.2 ab | 1,236.1 c | 1,984.7 cd |
| EVDT99WSTR | 1.57 a | 1.24 bc | 1.40 a-d | 75.7 a | 95.7 b | 85.7 ab | 2,666.6 ab | 1,694.4 c | 2,180.5 cd |
| LNTP x LNP W C3 | 1.38 ab | 1.23 bc | 1.31 a-d | 77.3 a | 95.0 bc | 86.2 ab | 2,833.3 ab | 1,972.2 bc | 2,402.8 bc |
| ACR94TZEWPOPSTR | 1.32 a-c | 1.16 b-d | 1.24 cd | 90.0 a | 88.7 b-e | 89.3 ab | 2,622.1 ab | 1,194.4 c | 1,908.3 cde |
| 2009TZEWDTSTR | 1.45 a | 1.33 a-c | 1.39 a-d | 71.0 a | 81.0 c-e | 76.0 b | 3,011.0 ab | 2,722.2 ab | 2,866.6 ab |
| LOCAL CHECK | 1.03 c | 0.65 d | 0.84 e | 74.3 a | 116.7 a | 95.5 a | 1,600.0 d | 1,167.7 c | 1,383.3 e |
| SE | 0.165 | 0.253 | 0.156 | 17.2 | 6.98 | 9.14 | 350.10 | 432.7 | 285.20 |

Means followed by the same letter (s) in a column are not significantly different at 5% level of probability, according to Duncan Multiple Range Test (DMRT).

Table 5 - Linear correlation coefficients (r) among growth and yield parameters of 13 maize varieties for 2011 and 2012 combined mean.

| Parameter | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 1. ASI | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 2. Ears plant$^{-1}$ | -0.133 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 3. Ear weight | 0.137 | -0.59*** | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 4. Days 50% silk | 0.362** | -0.152 | 0.093 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 5. Days 50% tassel | 0.189 | -0.126 | 0.059 | 0.981*** | 1.0 | 1.0 | 1.0 | 1.0 |
| 6. Ear height | 0.230* | -0.054 | 0.073 | 0.416*** | 0.394*** | 1.0 | 1.0 | 1.0 |
| 7. Grain yield ha$^{-1}$ | 0.040 | 0.565*** | -0.198 | 0.224* | 0.237* | 0.231* | 1.0 | 1.0 |
| 8. Plant height | 0.231* | -0.129 | 0.201 | 0.204 | 0.168 | 0.701*** | -0.034 | 1.0 |
| 9. Striga count | -0.077 | -0.036 | -0.062 | 0.315** | 0.341** | 0.176 | 0.115 | 0.016 |

ASI = Anthesis- silk interval. *, **, *** significant at $P < 0.05$, $P < 0.01$, and $P < 0.001$, respectively. Values without asterisk (s) have no significant linear correlation. D.F. = 11

eties significantly realized higher grain yield than the Local Check, Pool 18 SR, ACR 94 TZE W POP STR, TZE COMP3 DT WC2, EVDT 2000 Y STR QPM, EVDT 99 W STR and LNTP x LNP WC3 for the combined mean, respectively. There was no significant difference in grain yield of the three superior varieties with those of 2004 TZE W DT STR C4 and 2009 TZEW DT STR for the combined mean. These five varieties were the most prolific and thus realized superior grain yield. The Local Check, EVDT 2000 Y STR QPM and TZE COMP 3DT WC2 that were the least prolific and had superior ear weight significantly realized the least grain yield. Thus the prolificacy of a maize variety was the major determinant of grain yield in the present study. Kling et al (1997) also found significant positive correlation between grain yield and ears per plant.

The linear relationship among the agronomic parameters of the maize varieties showed that grain yield per ha was positively associated with ears per plant, days to silk, days to tassel and ear height (r = 0.22* to 0.56***) (Table 5). Thus grain yield increased with increase in number of ears per plant, number of days to flowering and ear height. Mason et al (1974) reported that dry matter yield showed a significant positive correlation to plant height and to ear height. Ears per plant, which is a measure of barrenness, were very strongly related to grain yield. Ears per plant was negatively correlated with ear weight (r = -0.59***), which explains the superior yield realized by varieties that were more prolific but with low ear weight. Thus ear prolificacy and ear weight were mutually exclusive for increasing grain yield. The ASI was positively correlated with plant height, ear height and days to silk (r = 0.23* to 0.36**). Taller varieties had longer ASI and prolonged period to silk which probably interfered with 'nick' timing due to drought. Drought stress accelerate pollen shed, often resulting in a poor timing 'nick' between pollen shed and silk emergence. Varieties with prolonged ASI realized lower grain yield probably as a result of incomplete ear filling as increase in ASI reduces number of kernels per ear (Sangoi et al, 2002).

The varieties selected by the farmers as promising during the field day were EVDT 2000 Y STR QPM, 2009 TZE W DT STR, EVDT 99 W STR QPM, 2008 DTMA Y STR, and DTY STR SYN. The farmers' criteria for variety acceptance were in the order: Striga tolerance > nutritive value > drought tolerance > flour value > good taste > high yield > early maturity (Table 6). The top ranking requirements in a variety were Striga tolerance (STR), presence of high quality nutrient such as quality protein as in quality protein maize (QPM) and beta carotene as in yellow maize (Y); and drought tolerance (DT). Most of the varieties preferred by the farmers' right from the field coincidentally exhibit two or more of these attributes. Kamara et al (2006) reported that farmers in market driven systems preferred early maturing and high yielding drought tolerant maize varieties, while those in relatively low resource production system preferred extra-early maturing varieties to provide food security than high yielding varieties. The trend in the present study showed farmer preference for nutritive maize and mitigation of environmental stress accentuated by Striga and drought.

### *Conclusions*

The response of the maize varieties tested to the biotic and abiotic constraints prevalent in the study

Table 6 - Pair-wise ranking of farmer criteria for selection of maize variety.

| Farmer criteria | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Total Score | Rank |
|---|---|---|---|---|---|---|---|---|---|
| 1. Nutritive value | x | 1 | 3 | 1 | 1 | 1 | 1 | 6 | 2nd |
| 2. Early maturity | | x | 3 | 4 | 5 | 6 | 7 | 0 | 7th |
| 3. Striga control | | | x | 3 | 3 | 3 | 3 | 7 | 1st |
| 4. Drought tolerance | | | | x | 4 | 4 | 4 | 4 | 3rd |
| 5. High flour value | | | | | x | 5 | 5 | 3 | 4th |
| 6. High yield | | | | | | x | 7 | 1 | 6th |
| 7. Good taste | | | | | | | x | 2 | 5th |

area was positive. Most of the varieties tested performed better than the local check across the two years of the study. The qualities exibited by the new maize varieties falled within the farmers criteria of stress tolerance and nutrients biofortification. Five varieties that were exeptionally adaptable and preffred by the farmers: DTY STR SYN, 2008 DTMA-Y STR, 2004 TZE-W DT STRC4, 2009 TZEW DT STR and EVDT 99-W STRQPM are recommended for testing in on-farm demeonstrations and adoption for improving maize productivity in the region.

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