Yield and Growth Performance of Drought Tolerant Maize Varieties in the Forest-Savanna Transition zone of Ghana

K. Agyeman, I. Osei-Bonsu, J. N. Berchie, S. Yeboah, L. M. Tengan, P. Marno, Asamoah Adjei and M. Apraku,
CSIR - Crops Research Institute (CSIR-CRI), P.O.Box 3785, Kumasi, Ghana

Corresponding Author: agyemanken@yahoo.com

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Abstract
Drought stress has deleterious effects on seedling establishment, vegetative growth, photosynthesis, root growth, anthesis, anthesis-silking interval, pollination and grain formation in maize crop. Drought is a major constraint to crop production in many tropical cropping systems where irrigation use is low and rainfall distribution is erratic. As a result of this, the performance of maize (Zea mays L.) in the major producing areas of Ghana is below its potential yield. The study evaluated drought tolerant maize varieties in the forest transition zones of Ghana. The study was carried out at Techiman and Wenchi districts both in the Forest Savannah transition agroecology in the minor season of 2013. The objectives of the study were to determine the performance of drought tolerant maize in the drought prone areas of Ghana using researcher managed mother and farmer managed baby trial design. For each of the parameters measured such as mean grain yield and non-productive parameters, the improved varieties performed better than the local varieties probably due to a prolonged mid-season dry spell, which coincided with silking and grain filling stages and affected the performance of the non-drought tolerant varieties. Mean grain yields ranged between 5195 and 6831 kg/ha and 3679kg/ha and 5225 kg/ha for the early maturing mother and baby trials, respectively. Yields ranged from 3638 to 6203 kg/ha and 2246 kg/ha to 6073 kg/ha for medium maturing mother and baby trials, respectively. Several drought tolerant varieties were identified as promising and a strategy is needed to achieve widespread adoption of these varieties in drought prone areas of Ghana. In general, the use of drought tolerant maize is seen as a panacea in mitigating the menace of climate variability on maize productivity in Ghana.

Keywords: Drought tolerance, Maize, Hybrids, Mother and Baby, Participatory

Rendement et Croissance des Variétés de Maïs Tolérantes à la Sécheresse dans la Zone de Transition Forêt-Savane du Ghana

Résumé
Le stress dû à la sécheresse a des effets néfastes sur l'établissement des semis, la croissance végétative, la photosynthèse, la croissance des racines, l'anthèse, l'intervalle anthésis-silking, la pollinisation et la formation des grains dans les cultures de maïs. La sécheresse est une contrainte majeure pour la production agricole dans de nombreux systèmes de cultures tropicales où l'utilisation de l'irrigation est faible et la distribution des précipitations irrégulière. Par conséquent, la performance du maïs (Zea mays L.) dans les principales zones productrices du

Ghana est inférieure à son rendement potentiel. L'étude a évalué les variétés de maïs tolérantes à la sécheresse dans les zones de transition forestière du Ghana. L'étude a été réalisée à Techiman et Wenchi, tous deux dans l'agroécologie de transition de la savane forestière au cours de la saison mineure de 2013. Les objectifs de l'étude étaient de déterminer la performance du maïs tolérant à la sécheresse dans les zones sujettes à la sécheresse du Ghana en utilisant le modèle d'essai géré par les chercheurs et les agriculteurs. Pour chacun des paramètres mesurés tels que le rendement céréalier moyen et les paramètres non productifs, les variétés améliorées ont obtenu de meilleurs résultats que les variétés locales, probablement en raison d'unela saison sèche, qui a coïncidé avec les étapes d'envasement et de remplissage des grains et a affecté la performance des variétés non résistantes. Les rendements céréaliers moyens variaient entre 5195 et 6831 kg/ha et 3679kg/ha et 5225 kg/ha pour les essais sur les mères et les bébés en phase de maturation précoce, respectivement. Les rendements variaient de 3638 à 6203 kg/ha et de 2246 kg/ha à 6073 kg/ha pour les essais de maturité moyenne des mères et des bébés, respectivement. Plusieurs variétés tolérantes à la sécheresse ont été identifiées comme prometteuses et une stratégie est nécessaire pour parvenir à une adoption généralisée de ces variétés dans les zones sujettes à la sécheresse du Ghana. En général, l'utilisation de maïs résistant à la sécheresse est considérée comme une panacée pour atténuer la menace de la variabilité climatique sur la productivité du maïs au Ghana.

Mots clés: Tolérance à la sécheresse, Maïs, Hybrides, Mère et bébé, participative

Introduction

Maize (*Zea mays*) is an important cereal in Ghana and one of the worlds` three primary cereal crops. In Ghana, maize is cultivated extensively by smallholder farmers throughout the country. It is the staple food of many tribes and is used to prepare many Ghanaian delicacies. Maize is the 7th largest agricultural commodity in terms of value of production over the period 2005-2010 accounting for 3.3 percent of total agricultural production value (FAOSTAT, 2012).

Nevertheless, maize growing environments in Ghana and sub-Sahara Africa in general are mainly rain-fed and characterized by erratic rainfall patterns, which are highly variable in both amount and distribution. As a result, the crop frequently suffers from moisture stress at some critical stages during its growth period (Johnston *et al*., 1986) with the ultimate result of reduced yields. Maize is generally intolerant to drought and according to Ashley (1999) early-season drought may hinder establishment of maize seedlings, whereas drought at flowering or grain filling stages could reduce yield or lead to total crop failure. These among other factors contribute to the yield gap between potential and actual yields at the farmer level.

Ghana recorded an average production increment of 12.6% from 1.66 million metric tonnes in 2011 to 1.87 million metric tonnes in 2012 (SRID, 2013). However, the annual domestic deficit in maize, the largest staple crop in the country, is estimated to be between 84,000 and 145,000 metric tons. This represents a shortfall in domestic production of between 9 and 15 percent of total human consumption. Domestic maize production fell from 1,871,695 metric tonnes in 2010 to 1,683,984 metric tonnes in 2011, representing a decrease in production of the staple crop by 11 percent (MoFA, 2012).

In addressing production deficit by researchers, a collaborative effort between the International Institute of Tropical Agriculture (IITA) and national maize improvement programmes in West and Central Africa (WCA), identified high yielding and stress tolerant maize varieties and hybrids. Participatory plant breeding/selection has shown success in identifying preferred varieties by farmers in shorter time (than the conventional system), in accelerating their dissemination and increasing cultivar diversity (Weltzien *et al*, 2003). Since farmers serve as the ultimate beneficiaries of the maize varieties, there is the need to involve farmers in selecting suitable varieties under their socio-economic and agro-ecological circumstances at very early or advanced stages. This is to bridge the yield gap between breeders and farmers and to ensure that new varieties satisfy farmers' preferences and suit their socioeconomic situations. As a result, breeders avoid wholesale release of varieties which might not be suitable varieties under farmers socio-economic and agro- ecological circumstances.

This study was conducted under the auspices of the Drought Tolerant Maize for Africa (DTMA) Project supported by the Bill and Melinda Gates foundations to obtain farmers' input and feedback on the selection of DT maize varieties that are in advance stages of development or ready for release using mother and baby trial design. The mother and baby trial design is a new approach to on-farm research consisting of a subset of central researcher-managed “mother' trial comprising all varieties/technologies being tested and satellites or “baby' trials, which are farmer-managed and test a subset of varieties from the mother trial (De Groote et al., 2002).

Materials and Methods

Field trials were conducted to assess farmers' input and feedback on the selection of Drought Tolerant Maize (DTM) varieties using mother and baby trial design during the 2015 minor cropping season (August-December) at six sites within the Techiman South and Wenchi Districts in the Brong Ahafo region (BAR) of Ghana. The Brong Ahafo region is located within longitude 00 15' E-30 W and Latitude 80 45' N-70 30' S in the west central part of Ghana. The southern and eastern parts have rather low elevations not exceeding 152.4 m above sea level. The predominant vegetation zones are the moist semi-deciduous forest, transitional and the Guinea savanna woodland roughly representing the southern, middle and northern parts of the region respectively. Three main soil groups are found within the region namely: Forest Ochrosols, covering the south-western part; Savanna Ochrosols, this stretches as wide belt from the west and gradually narrows toward the east and the ground water Laterite Ochrosols. This intergrades in the northern parts of the Region. Both sites are characterized by erratic and poorly distributed bimodal rainfall, averaging about 1,088 – 1,197mm per annum (MoFA, 2015).

A total of 12 mother trials (six sets each of early and medium maturing varieties) and 18 baby trials were planted between August and September, 2015 in seven farming communities around Wenchi and Techiman in the forest-savannah transition zone of Ghana. Four early maturing maize lines viz.: TZEI 7 x TZEI 26, TZEI 25 x TZEI 124, TZE-W Pop DT STR C4 x TZEI 17 and TZE-Y Pop DT STR C4 x TZEI 17, and a farmers' preferred variety were evaluated in farmer fields. The mother trials for the medium/ late maturing DT maize consisted of seven medium/ late maturing DT maize hybrids namely: M0926-2, M1026-3, M1026-7, M1126-2, M1126-5 and M1227-3, and a local check or Farmers' variety.

Plant spacing of 75 cm x 40 cm and 80 cm x 40 cm were used for early and medium maturing varieties, respectively. Each plot consisted of five rows 5.0 m long and replicated three times at each location. Baby trials were not replicated and contained two drought tolerant varieties/hybrids selected from the mother trial and a local check with plot size of 20 m x 20 m each using the same spacing as the mother trials. Varieties tested in the baby trials were selected from the mother trials by farmers and each farmer represented a replicate. Three seeds were planted per stand and thinned to two seedlings per stand at one week after planting (WAP), to give a target population of 66,600 and 62,500 plants/ha for early and medium maturing maize, respectively. Weeds were controlled using hand hoe at 2 and 4 WAP. Data on plant height at flowering, flowering date (days to 50% anthesis) were collected.

Grain yield was determined by harvesting the central two rows of each plot after physiological maturity in the mother trial and an area of 10 m x 10 m in the baby trials. Grain yield was calculated based on 80% shelling percentage and corrected to a 15% (150 g Kg^{-1}) moisture basis. Varieties were evaluated by farmers at tasseling and at harvest. Farmers at the tasseling stage scored each variety for earliness and at harvest, the varieties were scored for cob size, grain color, disease resistance, drought tolerance and yield. Each criterion was scored on a scale of 1-9 (1 = very important and 9 = least important) (De Groote et al., 2002). At both tasseling and harvest, farmers were asked to give an overall assessment of each variety, using the same scale.

Data collected were subjected to analysis of variance (ANOVA) using GENSTAT software Discovery Edition 4. Varietal means for each of the variables were separated by the Standard Error of Difference (SED) when the ANOVA showed significant differences ($P < 0.05$). Descriptive statistics (simple percentages) were used to compare frequencies of respondents with respect to farmers' choice of variety and their perceptions on the varietal choice.

Results

Evaluation of Early Maturing set: Mother trial

The results of the mother trials for the early maturing DT maize varieties/ hybrids are presented in Tables 1 and 2. The early maturing varieties revealed a distinct statistical variation in most agronomic traits and also there was significant difference ($P<0.05$) between the new varieties and the local checks. As indicated in Table 1, days to mid-tasseling among the drought tolerant early maturing varieties ranged from 52 to 59 days at Awisa; 53 to 63 at Wenchi and 50 to 52 at Forikrom. Across locations, days to mid tasseling ranged from 51 to 57 days (Table1). The farmers' variety was the last to reach mid-tassel stage at all locations.

The DT maize varieties/ hybrids attained mid-silking significantly ($p<0.05$) earlier than the farmers` variety. Days to 50% silking followed a similar trend as the days to 50% tasseling. Across locations tasseling and silking of the farmers' variety was late (57 and 63 days, respectively), while the range for the drought tolerant varieties were 51-53 days and 56-57 days, respectively (Table 1*)*.

In other words, the combined analysis result for early set mother trial showed that there was significant difference among the varieties for days to mid tasseling and silking in 2015 except at Forikrom where there were no significant difference among the drought tolerant varieties.

As indicated in Table 2, TZEI 7 x TZEI 26 had the highest grain yield (6831 kg ha^{-1}) across locations and out-yielded the farmers variety (5195 kg/ha) by 23 %. TZEI 25 X TZEI 124 (6185 kg/ha) and TZE-W Pop DT STR C4 X TZEI 7 (5565 kg/ha) out yielded the farmers variety by 16 % and 7 % respectively. Maize grain yields of DT varieties were relatively higher than the farmer variety during the 2015 minor planting season with an average grain yield of 5787 Kg/ha. In general, yields in Forikrom were lower than yields in Awisa and Wenchi.

Baby trial

In early maturing baby trial, the same varieties evaluated on farmer's field showed similar response as the mother trial. The result of early maturing baby trial showed significant difference for most agronomic traits measured in the two communities and across location. The highest grain yield was obtained from TZEI 7 X TZEI 26 (5576 $kgha^{-1}$ and 4873$kgha^{-1}$) at Forikrom and Awisa respectively (Table 3). The early maturing

Table 1: Days to 50% tasseling (DFT) and 50% silking (DFS) of early maturing Drought Tolerant Maize (DTM) genotypes tested on-farm in three communities in the forest-savannah transition zone of Ghana during the 2015 minor cropping season

Variety	Awisa		Wenchi		Forikrom		Across Locations	
	DFT	DFS	DFT	DFS	DFT	DFS	DFT	DFS
TZEI 7 x TZEI 26	54	56	53	58	51	58	52	57
TZEI 25 x TZEI 124	53	56	53	57	50	57	51	56
TZE-Y Pop DT STR C4 x TZEI 17	52	54	53	58	51	58	52	56
TZE-W Pop DT STR C4 x TZEI 7	53	56	54	57	51	57	53	57
Farmers variety	59	65	63	70	52	58	57	63
CV	1.6	0.5	0.9	0.8	2.8	1.1	0.7	0.7
SED	0.5	0.26	0.73	0.3	1.2	0.5	0.9	0.2

Table 2: Grain yield of early maturing drought tolerant maize genotypes tested on-farm in three communities in the forest-savannah transition zone of Ghana during the 2015 cropping season

Variety	Grain yield ($Kg\ ha^{-1}$)			
	Awisa	Wenchi	Forikrom	Across Locations
TZEI 7 x TZEI 26	7242.7	8516.4	4735.3	6831
TZEI 25 x TZEI 124	6376.9	7757.7	4421.6	6185
TZE-Y Pop DT STR C4 x TZEI 17	5244.1	5371.0	4882.3	5165
TZE-W Pop DT STR C4 x TZEI 7	6165.0	6622.0	3882.4	5565
Farmers variety	6359.7	5532.0	3698.0	5195
CV	18.4	13.14	28.0	22.0
SED	944.9	725.0	1341.7	1226

drought tolerant hybrids from IITA out yielded the farmer variety by 41.4 % across the two locations in 2015.

Evaluation of Medium / Intermediate maturing drought tolerant maize varieties

Mother trial

Tables 4 and 5 show the performance of the medium maturing varieties across four locations in the transitional zone of Ghana. Generally, the intermediate maturing varieties performed well in these locations compared with the local check. Significant ($p<0.05$) differences were observed among varieties in days to 50% tasseling, mid-silking and grain yield across locations (Table 4). Medium maturing DT maize genotypes / hybrids attained 50% tasseling significantly earlier than the farmers` variety. Days to 50% silking followed a similar trend like days to 50% anthesis. Farmers` varieties produced silk and tassel later than the improved varieties (Table 4).

Drought Tolerant medium hybrid M0926-2 had the highest grain yield (6203 kg/ha) across locations and out-yielded the Farmers' variety by 41.3 % (Table 5). Significant ($p<0.05$) differences were observed among genotypes in grain yield across locations in the baby trials (Tables 6 and 7). The Farmers' variety tasselled later than the DT maize varieties but produced lower yields as compared to the improved varieties.

Baby trial

In general, precipitation in 2015 was lower in these sites. Consequently, maize grain yield was consistently low during the short rainy season in 2015 at both sites. Tables 6 and 7 showed means of grain yield, days to mid-tassel and days to mid-silking of drought tolerant and local checks evaluated in baby trial the minor cropping season of 2015. There were significant differences between the drought tolerant hybrids and the local checks for grain yield, days to mid-tassel and days to mid-silking across the two locations. The yields were higher for drought tolerant maize varieties when compared with the local checks (Tables 6 and 7). This is indication of the differences in the genetic compositions of the improved variety and the local check.

Discussions

The locations which were identified by farmers as being drought prone and were therefore selected for the experiments actually had lower rainfall distribution and frequency. After planting, there were clear

Table 3: Grain yield, days to mid tassel (DFT) and days to mid silking (DFS) of early maturing DT maize genotypes tested in Baby Trials in 2015 minor cropping season

Variety	Awisa			Forikrom			Across Locations		
	Grain yield (kg/ha)	DFT	DFS	Grain yield (kg/ha)	DFT	DFS	Grain yield (kg/ha)	DFT	DFS
TZEI 7 x TZEI 26	4873	49	56	5576	50	52	5225	50	54
TZEI 25 x TZEI 124	4392	49	56	4632	53	60	4512	51	58
Farmers variety	4094	60	65	3264	62	70	3679	61	68
CV	7.2	2.5	11.6	17.3	11.6	2.5	8.8	1.4	3.6
SE	321	1.3	4.1	773	1.4	6.9	393	0.8	2.2

Table 4: Days to 50% tasseling (DFT) and 50% silking (DFS) of intermediate/late maturing DT maize varieties tested across three farming communities in the forest-savannah transition zone of Ghana in the Mother trial

Variety	Pramposo		Awisa		Wenchi		Asante Nkuraa		Across Locations	
	DFT	DFS	DFT	DFS	DFT	DFS	DFT	DFS	DFT	DFS
M1026-7	55	61	58	62	60	66	56	60	657	63
M1126-2	50	60	57	61	60	65	56	59	56	61
M0926-2	58	63	57	62	61	66	57	61	58	63
M1026-3	55	63	59	62	61	65	57	60	58	62
M1126-5	50	61	58	62	60	66	55	59	56	62
M1227-3	55	61	59	62	60	68	56	61	58	63
Farmers variety	58	64	59	62	71	76	57	63	61	66
CV	2.4	2.54	2.2	2.2	0.93	0.44	3.4	3.4	6.3	5.2
SED	1.1	1.2	1.0	1.1	0.3	0.2	1.5	1.7	1.4	1.3

Table 5: Grain yield of intermediate/late maturing DT maize varieties tested on-farm across three locations in the forest-savannah transition zone of Ghana in the Mother trial

Variety	Pramposo	Awisa	Wenchi	Asante Nkuraa	Across Locations
M1026-7	5028	3952	4717	4678	4593
M1126-2	5420	4750	5016	5645	5207
M0926-2	6006	6497	6911	5398	6203
M1026-3	4690	4357	4020	5525	4648
M1126-5	5571	5666	5388	5647	5568
M1227-3	6148	4890	4240	5481	5189
Farmers variety	3894	3565	3401	3694	3638
CV	10.79	28.0	26.5	25.2	13.6
SED	651	1363	1507	1020	1006

evidence of drought during the early stages of growth and this was mainly attributed to the harsh impact of climate variability on agriculture in Ghana. Nonetheless, the impact of drought was lower on the drought tolerant hybrids compared with farmer varieties which showed clear impact of drought on the growth and yield of the crop. This implies that planting drought tolerant varieties provides an outstanding yield and growth advantages over varieties that are not drought tolerant.

Drought is a major constraint to crop production. Drought reduces crop yields and leads to potential yield losses (Golbashy *et al.*, 2010). Annual yield loss due to drought is about 24 million tons, which is about 17% of a normal year's production in the developing world (Edmeades *et al.,* 1992). Although breeding for high yielding varieties in particular is a prerequisite to enhancing food security, high awareness of drought tolerant hybrids is necessary for high adoption in drought prone areas of production. Predominantly in most farming areas, irrigation facilities are limiting and thus expose the vulnerability of agriculture as a result of climate variability. Drought coupled with soil fertility decline accounts for the low yields of 1.8 t/ha instead of potential yield of 6-7 t/ha in the Sub-Sahara Africa.

In order to overcome these challenges, a conscious effort that aims at breeding for stress tolerant varieties to replace the vulnerable varieties with little or no tolerance to drought is essential. This is imperative for a sustainable maize production in Ghana where our farming systems are characterized by rain-fed agriculture. This is evident by the superiority of the DT hybrids over the farmer own varieties.

From this trial, it is obvious that the production of drought tolerant maize hybrid is a potentially profitable enterprise in the Transition zone of Ghana. The results of the study showed the superiority of the drought tolerant hybrids/varieties over the local checks. The yield increase with the drought tolerant varieties was likely due to better tolerance of the varieties to water and nutrient stress. Increase in maize yield as a result of the varieties tolerance to drought has also been reported by Edmeades and Deutsch (1994) and Buah *et al*. (2013) and a better synchronization of its growth with nutrient availability (Agyeman *et al*., 2013; Agyeman *et al*., 2012)

The results of the growth and yield having positive relationship with the grain yield are expected as reported in other studies. Gemenet *et al*. (2010) reported highly significantly positive correlation (r=0.91**) for kernel number with grain yield and relatively high correlations (r=0.54) of ear number with grain yield. These results also confirm the genetic basis of the phenotypic findings by Xiao *et al.* (2005) that ear number, kernel number and ear weight directly influence grain yield.

Significant differences among the varieties that were observed for days to silking and days to anthesis is an indication of the differences in micro environment of the planting sites and genetic make-up of the maize evaluated in this study including local checks which has not been improved for drought tolerance. The days to mid-silking and mid-tasseling of the local check was longer compared with the DT hybrids under similar growing conditions. The observation that the farmers' variety tasselled and silked later than the early maturing varieties is similar to observations made by Asumadu *et al*. (2011) and Buah *et al*. (2013) for experiments in the forest-savannah transition and Guinea savannah zones respectively.

Ear length and weight are controlled by genotypic and environmental factors such as nutrient and water content (Agyeman *et al*., 2013). Since ear contains kernels and has been reported as an important part of yield, so has more ear length, and more kernels lead to higher yield. Thus, the inherent potential of these drought tolerant varieties to maintain higher ear weight under drought conditions exhibits its superiority over local varieties which have not been improved for drought tolerance. This is imperative towards enhancing food security under worsening climatic variability in Ghana.

The overall low yields of the local check can be attributed to the poor tolerance of the varieties to drought. A prolonged mid-season dry spell, which coincided with silk emergence and grain filling stage, was experienced during 2015 evaluation. Precipitation when evenly distributed during the growing season greatly affects soil moisture content and thus influences N mineralization and availability and subsequent maize growth and uptake. Thus, in drier seasons, reliance on drought tolerant varieties could be more profitable. Although substantial crop yields can be achieved from the local varieties through applying mineral fertilizers, most smallholder farmers in the transition zone of Ghana rarely use fertilizer because of high cost and low and variable returns. Any new technology that aims at enhancing food security and improving livelihood of the smallholder farmer should have options that are viable in the short and long term in order to be attractive to smallholder farmers. This must involve the selection of varieties that are high yielding, high nutrient use efficiency which are adapted to climate variability (drought tolerant). Fertilizer use efficiency is improved when water is available otherwise the use of fertilizers alone in the absence of water would not lead to increase in grain yield of maize.

Conclusion

Farmers in the selected farming communities responded positively in the assessment of the new varieties they evaluated based on grain yield and other non-reproductive parameters. In most cases in the baby trials, hybrid varieties showed superior performance as compared to the farmers' variety which showed poor performance in terms of yield and growth parameters. The lateness of the farmers' variety in anthesis and silking and subsequently in maturity in the early maturing mother trial did not translate into higher yield as expected, but gave relatively lower yield as compared to the improved varieties. In most of the medium maturing baby trials, the Farmers' variety showed poor performance as compared to the drought tolerant hybrid M1026-3. Farmers appreciated the performance of the hybrid M1026-3 in most of the locations during the field days.

Drought affected the morphological and physiological behavior of maize hybrids. Among the DT early maize hybrids TZEI 7 x TZEI 26 performed best. In the medium mother trial, the hybrid with the highest yield was M 0926-2. However, in the medium Baby trials at Forikrom and Asueyi, M 1026-3 performed better than M 1126-5 and the farmer variety.

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