Research in Plant Biology, 5(6): 19-29, 2015 ISSN : 2231-5101
www.resplantbiol.com

Regular Article

Evaluation of some genotypes of maize (*Zea mays* L.) for tolerance to drought in Northern Ghana

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Pot and field studies were conducted to screen twenty five genotypes of maize for tolerance to drought in Northern Ghana during the 2012 and 2013 cropping seasons. For the pot studies, seeds were planted in June 2012 in 0.20 m × 0.30 m surface pots arranged in rows on a platform with a distance of 1 m between the rows. After emergence, 2 l of water was applied to the plants in each pot, once every week for the non-stressed treatments (control). To mimic drought conditions, the same amount of water was applied, but once every two weeks to the stress treatments. Treatments were replicated three times in a completely randomized design. For the field study, genotypes were evaluated on single-row plots of three replicates, in a randomized complete block design. Plants designated as control were planted at the normal and usual time of planting of maize in the study area (July 2013), whilst those subjected to water-stressed treatments were planted late (six weeks later) to ensure that their growth period coincides with the drought period. Results on yield and agronomic parameters showed that three of the genotypes (GUMA03-OB, KOBN03-OB and SISF03-OB) were highly tolerant to drought, whilst eleven genotypes (NYAZ04-W, TAAN04, TAIS03, TZE-Y-DT-STR-C4, NYSW03-Y, NYIA03, DORKE SR, TZE-W-DT-STR-C4, NYFA04, KOBN04-R, and CHMA04) were moderately tolerant. The rest of the genotypes showed moderate to high levels of drought susceptibility. Drought plant rating and anthesis-silking interval (ASI) were significantly reduced when plants were watered throughout the experimental period (control) as compared to those stressed. However, grain yield, plant height, ear height, days to 50% anthesis, days to 50% silking, leaf area, chlorophyll content, fresh and dry shoot weight and root length were significantly higher ($P < 0.05$) for the non-stressed plants as compared to those subjected to water stress. In drought-prone geographical areas like Northern Ghana, genotypes such as GUMA03-OB, KOBN03-OB and SISF03-OB or their crosses can be used for increased grain yield.

Keywords: Maize; drought tolerance; savanna; Ghana

Maize is a staple food that constitutes the main diet of many people in tropical and subtropical Africa (Oyekan *et al*., 1990). It's importance has increased as it has replaced other staple foods such as sorghum and millet (Smith *et al*., 1994), and it has also become a major source of cash for smallholder farmers (Smith *et al*., 1997). Maize has been a widely consumed staple *et al*., 1999). It is an important cereal, produced in all the five agro-ecological zones of Ghana (Obeng- Bio *et al*., 2002). Analysis based on 1987 maize consumption data in Ghana showed that maize and maize based foods accounted for 11% of food expenditure by the poor, and 10% of food expenditure by all income groups (SARI, 1996). Maize is grown on one million hectares of land in Northern Ghana (Dowswell *et al*., 1996).

In spite of the enormous role that the maize industry plays in improving the lives of the people of Ghana and the world at large, it is faced with a lot of constraints. These include lack of credit facilities to the farmers, soil degradation, erratic rainfall pattern, diseases, insect pests and weeds. In Africa, the problems of erratic rainfall pattern enormously affect maize

production in particular and agricultural potential in general. Drought is a major source of grain yield decrease in cereals, especially in developing countries. Maize grain losses due to drought in the tropics may reach 24 million tons per year, equivalent to 17% of well-watered production (Edmeades *et al*., 1992). Regional grain losses due to drought may reach 70% under extreme conditions, compared with well-watered productions (Edmeades *et al*., 1995). Maize production in the Northern Region of Ghana has not been very encouraging. There was an increase in production from 106,700 tons in 1990 to 159,460 tons in 1991, and a decrease in production to 130,560 tons in 1992 (PPMED, 1992). This reduction in yield was due to irregular onset and distribution of rains.

The increasing world's population requires more food; and maximum part of this food will come from the maize crop (Ali and Yan, 2012). It has been estimated that more than half of the increase in demand of world food in terms of cereals as a whole will be produced by maize farmers (Yan *et al*., 2011). Breeding for drought resistance/ tolerance in maize may improve the performance of the crop even under water-stressed conditions. This study was therefore conducted to screen some genotypes of maize for tolerance to drought in Northern Ghana.

MATERIALS AND METHODS

Land preparation

The experiments were conducted at the experimental fields of the Savanna Agricultural Research Institute (SARI), and in the plant house of the Faculty of Agriculture, University for Development Studies, Nyankpala. In the field experiment, the field was ploughed and debris removed; it was demarcated using lines and pegs and leveled using a hoe before seeds of the genotypes were planted.

Experimental design

Twenty five maize genotypes, developed by the International Institute for Tropical Agriculture (IITA) were obtained from the Council for Scientific and Industrial Research Station (CSIR) - the Savannah Agricultural Research Institute (SARI), Nyankpala, and screened for drought tolerance during the 2012 and 2013 cropping seasons under pot and field conditions, respectively. The experimental design used for the pot study was Completely Randomized Design, whilst the Randomized Complete Block Design was used for the field experiment.

The genotypes used were CHFB04-OB, KPAS04, OKOMASA, KOBN03-OB, NYAZ03-Y, NYAZ04-W, GUMA03-OB, GBRM04-BA, TZE-Y-DT-STR-C4, DORKE SR, NYAN03, TZE-W-DT-STR-C4, NYIA03, NYLA04, TAAN04, NYSW03-Y, DT-STR-W-C2, SISF03-0B, KOBN04-R, TAIS03, CHMA04, IWD-C3-SYN-F2, NYFA04, GH120 DYF/D POP and NYFA03. For the pot experiment, four seeds of each genotype were planted in pots arranged in rows on a platform with 1 m alley between the rows. After emergence, seedlings were thinned to three plants per pot. Each pot measured 0.20 m × 0.30 m. An amount of 2 l of water was applied once every week to the control or non-stressed plants (here after referred to as normal watering or 'normal'). The same amount of water was applied once every two weeks to plants subjected to water-stressed treatments in the pots. This type of watering regime was closely observed from the beginning to the end of the experimental period. In the field study, there were two different planting regimes: the control treatments were made up of seeds that were planted at the normal and usual time of planting maize in the study area (July 2013), whilst the genotypes that were subjected to water-stress conditions were planted late (six weeks later) to ensure that their growing stage coincided with the drought period. In both cases, treatments were replicated three times. Blocks were separated from one another by a 2 m alley whilst the inter-row and intra- row spacings were 0.75 m and 0.40 m, respectively.

Cultural practices

In the case of the field study, pre-emergence chemical weed control was used. An application of a combination of Pendimethalin [N- (1- ethylpropyl) - 3, 4 – dimethyl –2, 6 – dinitrobenzenamine] and Gesaprim [2- chloro –4 – (ethylamino) –6- (isopropylamino) –5- triazine] at 1.5 l ha^{-1} and 1.0 l ha^{-1} rates were used at planting.

Where there was heavy weed growth prior to planting, Paraquat (1, 1- dimethyl –4, 4 – bipyridinium ion) was also applied at 1.0 l ha^{-1} in addition to Pendimethalin and Gesaprim. Hand weeding was also carried out to keep the plots free of weeds at 4 weeks after planting in both the pot and field experiments. Also in both experiments, basal fertilizer was applied at 2 weeks after planting at the rate of 30 kg N ha^{-1} and 60 kg P_2O_5 ha^{-1}. Four weeks after planting, plants were top-dressed with additional N at 30 kg N ha^{-1}.

Data collection and statistical analysis

Measurements were made at the vegetative stage of the plants at 6 weeks after plant establishment (WAPE). Parameters measured were leaf number, shoot length, chlorophyll content, leaf area, stem girth, fresh shoot weight, dry shoot weight, fresh root weight, dry root weight and root length. Also, between flowering and physiological maturity, data such as plant height, days to 50% anthesis, days to 50% pollen shed, days to 50% silking, anthesis – silking interval (ASI), ear height and drought rating were collected. Grain yield and yield components, such as hundred- grain weight and number of ears harvested per plot were also recorded. The data collected were subjected to Analysis of Variance (ANOVA) using Genstat statistical package and means separated using the Duncan's multiple range test at 5% level of probability.

RESULTS AND DISCUSSION

The results indicate that some genotypes are more tolerant to drought than others.

Screening under pot conditions

Plant growth, leaf development and relative chlorophyll content

A clear effect of drought stress on the various genotypes was observed on leaf development. There was variation in leaf number and leaf area between the control and plants under water stress. Leaf number in the water-stressed plants was reduced relative to that of the control (Table 1). This is in consonance with the findings of Quarrie and Jone (1977), who also observed that water stress greatly affects leaf and vegetative growth. They also observed an early termination of extension growth in perennial parts, which occurs with the formation of dormant buds. Their findings reveal that the water deficit increases abscission of leaves, and results in the reduction of cell expansion and cell division, which materializes in the less development of plant leaves and tissues. Similar explanations, but on leaf area have been provided by Pandey *et al*. (2000). In the present study, there was a highly significant variation ($P < 0.01$) in leaf number and leaf area among the water-stressed genotypes (Table 1). Genotype DT-STR-W-C2 recorded the highest number of leaves (6.67), whilst NYAZ03-Y and KOBN04-R recorded the least number (4.00). For leaf area, GUMA03-OB recorded the highest (71.33 cm^2), whilst NYLA04 recorded the least (30.82 cm^2). As similar environmental conditions prevail, the variations in leaf number, area and other growth properties are attributed to the inherent genetic variability of the different genotypes used. The result compares favorably with those obtained by Dai *et al*. (1990), who reported that moderate water stress inhibited the growth, development and yield of all cultivars and hybrids at different growth stages and that the leaf area of resistant cultivars remained larger under drought conditions.

There were significant differences ($P < 0.05$) among the water-stressed genotypes for plant height (Table 1). Genotype GUMA03-OB was the tallest (36.47 cm), whilst GH120 DYF/D POP was the shortest (22.33 cm). Plant heights were generally higher in the control treatments than the water-stressed plants (Table 1). This supports the observation by Pandey *et al*. (2000), who pointed out that increase in moisture stress in maize results in progressively less leaf area, crop growth rate, plant height, shoot dry matter and harvest index.

Chlorophyll plays a major role in photosynthesis, which ultimately determines the crop yield. Significant differences ($P < 0.05$) existed among genotypes with respect to chlorophyll content (Figure 1). In general, as in the case of the other traits, the water-stressed plants recorded lower chlorophyll content than those watered throughout the experiment. For crops grown under normal conditions, the genotype KPAS04 recorded

the highest chlorophyll content of 42.57, whilst CHMA04 recorded the lowest (28.13). For the water-stressed treatments, TZE-Y-DT-STR-C4 recorded the highest chlorophyll content of 38.37, whilst GUMA03-OB recorded the lowest chlorophyll content of 28.77. In maize production, physiologically developmental processes such as the formation and expansion of cells and development of green pigments are normally enhanced in soils with high moisture content. The variation in moisture content of the soil might have caused the variation in the levels of chlorophyll content of the maize genotypes. The results on chlorophyll content corroborates with the observation made by Terbea and Ciocazamu (1999), who reported that water stress significantly decreased photosynthetic rate, root length, lateral root area and chlorophyll contents in highly drought sensitive genotypes. Ouattar *et al*. (1987) also reported that water deficit in maize plants decreased chlorophyll content and hence, reduced photosynthetic rate and total plant dry weight of the maize plant.

Root growth, development and shoot dry matter production

In general, the dry matter accumulated by crop plants positively correlates with crop yield. Genotypes with the water-stressed treatment recorded significantly lower ($P < 0.05$) root dry matter than the control (normal) (Table 2). The normal treatments recorded the highest mean dry root weight of 0.70 g, whilst the water-stressed treatments recorded the least mean dry root weight of 0.21 g. The amount of root weight produced by a crop plant is dependent on the amount of photosynthate accumulations in the plant during the period of plant growth. The water-stressed condition could have caused the corresponding reduction in the amount of photosynthate accumulation, which consequently resulted in the reduction of root weight among the water-stressed treatments. This is in consonance with the observation made by Shiralipour and West (1984), that drought stress did not only reduced shoot weight but also dry and fresh root weight as well. Among the water-stressed treatments, NYSW03-Y recorded the highest root length of 19.23 cm, whilst KPAS04 and GH120 DYF/D POP recorded the lowest value of 9.40 cm each. Root lengths, recorded from the water-stressed treatments were also significantly lower ($P < 0.05$) than those from the normal (Table 2). The differences in root length, produced by the various genotypes under the water stressed conditions are attributed to variations in plant drought-resistant mechanisms associated with the different genotypes. A number of investigators, including Matsuura *et al*. (1996) and Ramadan *et al*. (1985) made similar observations. On the contrary, Mayaki *et al*. (1976) observed that maize roots penetrate deeper under conditions of moisture stress than they do when moisture is adequate.

The fresh and dry shoot weights significantly varied ($P < 0.05$) from one genotype to another (Table 3). In the water stressed treatments, some of the genotypes recorded higher shoot dry matter than others (Table 3), and this agrees with the observation made by Ashraf (1989), that drought tolerant cultivars produce higher shoot dry matter than the susceptible ones. Among the water-stressed treatments, CHFB04-OB recorded the highest dry shoot weight of 2.80 g, whilst NYLA04 recorded the lowest of 0.45 g. However, the genotypes CHFB04-OB, KPAS04, TAAN04 and TAIS03 did not significantly differ ($P \geq 0.05$) in their dry shoot weights (Table 3). The fresh and dry shoot weights produced from the water-stressed plots were also significantly lower ($P < 0.05$) than those from the normal plots and the disparity observed is attributed to adaptation to drought stress. The water stressed condition could have reduced the chlorophyll content in the plants, due to a reduction in physiological functions, resulting in a corresponding reduction in the amount of photosynthate accumulation (Thakur and Rai, 1984). This explains the reduction in dry matter content among the water-stressed treatments relative to the normal.

Screening under field conditions

Variations in plant height, days to 50% anthesis, days to 50% pollen shed, days to 50% silking and anthesis – silking interval

Significant variations ($P < 0.05$) exist in plant height among the genotypes (Figure 2). For the water-stressed treatments, GBRM04-BA recorded the highest plant

height of 174 cm, whilst NYSW03-Y recorded the least of 86 cm. In general, the plants from the normal treatments were significantly taller ($P < 0.05$) than those from the water-stressed treatments (Figure 2). The normal treatments recorded the highest mean plant height of 155 cm, whilst the water-stressed genotypes recorded the least mean of 138 cm. This supports the findings of Pandey *et al*. (2000), who reported that increasing moisture stress in maize resulted in progressively less crop growth rate, plant height, shoot dry matter and harvest index.

Table 1: Variation in leaf area, leaf number and plant height of different maize genotypes under normal and water stressed conditions in a pot experiment across the northern Savanna region of Ghana

Genotype	Number of Leaves		Plant height (cm)		Leaf Area (cm²)	
	Water-stressed	Normal	Water-stressed	Normal	Water-stressed	Normal
CHFB04-OB	6.00^{abc}	8.00^{abc}	30.67^{abcd}	65.80^{abc}	45.42^{cd}	136.5^{ab}
KPAS04	5.33b^{cde}	7.67^{abcd}	31.00^{abcd}	64.87^{abcd}	64.55^{abc}	150.7^{a}
OKOMASA	4.67d^{ef}	8.00^{abc}	33.03^{abc}	50.73^{fghi}	55.32^{abc}	87.2^{e}
KOBN03-OB	5.33^{bcde}	6.00^{e}	31.23^{abcd}	53.50^{defghi}	67.84^{ab}	113.4^{bcde}
NYAZ03-Y	4.00^{f}	6.33^{de}	27.63^{cdef}	61.20^{abcdefg}	51.16^{abcd}	95.6^{cde}
NYAZ04-W	5.67^{abcd}	7.33^{abcde}	33.17^{abc}	49.47^{fghi}	57.10^{abc}	106.2^{cde}
GUMA03-OB	6.33^{ab}	8.00^{abc}	36.47^{a}	66.23^{ab}	71.33^{a}	103.7^{cde}
GBRM04-BA	5.00^{cdef}	7.00^{bcde}	25.10^{def}	60.60^{abcdefg}	50.43^{abcd}	89.9^{de}
TZE-Y-DT-STR-C4	4.67^{def}	6.00^{e}	30.10^{abcde}	54.97^{bcdefghi}	51.06^{abcd}	99.6^{cde}
DORKE SR	5.33b^{cde}	8.67^{a}	27.80^{cdef}	59.60^{abcdefgh}	52.56^{abc}	107.5^{cde}
NYAN03	5.00^{cdef}	6.67^{cde}	28.13^{cdef}	58.10^{bcdefgh}	56.89^{abc}	118.47^{bc}
TZE-W-DT-STR-C4	5.33^{bcde}	8.67^{a}	35.80^{ab}	70.30^{a}	59.97^{abc}	109.0^{bcde}
NYIA03	5.67^{abcd}	8.00^{abc}	27.43^{cdef}	61.30^{abcdef}	47.28^{bcd}	97.1^{cde}
NYLA04	4.67^{def}	7.33^{abcde}	24.77^{def}	60.13^{abcdefgh}	30.82^{d}	104.4^{cde}
TAAN04	5.00^{cdef}	7.33^{abcde}	31.87^{abcd}	48.27^{hi}	64.94^{abc}	110.4^{bcde}
NYSW03-Y	5.67^{abcd}	7.33^{abcde}	23.07^{ef}	53.23^{defghi}	59.45^{abc}	115.9^{bcd}
DT-STR-W-C2	6.67^{a}	8.33^{ab}	33.17^{abc}	63.10^{cde}	62.06^{abc}	100.8^{cde}
SISF03-0B	6.00^{abc}	8.33^{ab}	33.13^{abc}	58.87^{abcdefgh}	57.68^{abc}	100.1^{cde}
KOBN04-R	4.00^{f}	6.33^{de}	28.43^{cdef}	53.80^{cdefghi}	48.97^{bcd}	108.9^{bcde}
TAIS03	5.67^{abcd}	7.33^{abcde}	28.60^{bcdef}	50.03^{fghi}	62.36^{abc}	108.4^{cde}
CHMA04	4.67^{def}	6.33^{e}	25.67^{def}	50.47^{fghi}	60.8^{5abc}	111.1^{bcde}
IWD-C3-SYN-F2	4.33^{ef}	8.33^{ab}	25.00^{def}	49.17^{ghi}	49.34^{bcd}	107.1^{cde}
NYFA04	6.33^{ab}	7.33^{abcde}	27.67^{cdef}	51.47^{efghi}	57.29^{abc}	108.4^{cde}
GH120 DYF/D POP	6.00^{abc}	8.00^{abc}	22.33^{f}	56.80^{bcdefgh}	44.91^{cd}	92.0^{cde}
NYFA03	5.67^{abcd}	6.67^{cde}	26.03^{cdef}	44.40^{i}	63.52^{abc}	96.3^{cde}
Mean	5.32	6.87	29.09	56.66	55.72	107.15
SEM	0.21	0.11	1.82	1.00	3.51	1.87

SEM = Standard error of mean; genotypes having the same letters (vertical direction) are not significantly different at the 5% level of probability

The anthesis-silking intervals were significantly higher in the water-stressed plots than they were in the normal plots (Figure 3). The trait significantly ($P < 0.001$) varied among the genotypes, especially within the water – stressed treatments. Drought, during flowering stage might have accounted for the wide range of variation among the genotypes for this trait. Inherent variability of individual genotypes could also have caused the wide variations among genotypes for the trait. This observation is in support of that by Rowland (1993), who noticed that drought prolonged the extrusion of silk from cob husk, and that a high temperature during the day also compounded this; resulting in tassel blast.

There were highly significant variations ($P < 0.001$) among genotypes with respect to days to 50% anthesis. Among the water-stressed genotypes, OKOMASA recorded the highest number of 64 days, whilst NYSW03-Y recorded the least number of 50 days (Table 4). This was possibly caused by the inherent genetic variability among the genotypes. Days to 50% anthesis were also significantly lower ($P < 0.05$) for plants cultivated under the water-stressed plots (57 days) as compared to those from the normal treatments (59 days).

Rowland (1993), attributed the reduction in days to anthesis among water stressed genotypes to the mobilization of water for the production of seeds before the end of the growing season. Similar observations have been cited by Angus and Moncur (1977), and also Morgan (1980).

Table 2: Variation in root biomass and root length of different maize genotypes under normal and water stressed conditions in a pot experiment across the northern Savanna region of Ghana

Genotype	Fresh root biomass (g)		Dry root weight (g)		Root length (cm)	
	Water-stressed	Normal	Water-stressed	Normal	Water-stressed	Normal
CHFB04-OB	1.35^{ab}	4.90^{a}	0.40^{ab}	1.25^{a}	16.27^{abcd}	21.35^{ab}
KPAS04	1.00^{abcde}	4.25^{abc}	0.27^{abcde}	0.85^{abc}	9.40^{h}	24.05^{a}
OKOMASA	1.17^{abc}	2.93^{abc}	0.27^{abcde}	0.73^{abc}	14.23^{bcdefg}	13.07^{efg}
KOBN03-OB	1.20^{abc}	2.40^{abc}	0.33^{abc}	0.43^{bc}	18.80^{ab}	14.73^{cdefg}
NYAZ03-Y	0.57^{de}	2.13^{abc}	0.07^{fg}	0.47^{abc}	9.53^{gh}	15.93^{bcdefg}
NYAZ04-W	1.33^{ab}	2.40^{abc}	0.43^{a}	0.53^{abc}	12.57^{defgh}	21.30^{ab}
GUMA03-OB	1.30^{ab}	2.00^{bc}	0.35^{abc}	0.40^{c}	16.50^{abcd}	16.33^{bcdefg}
GBRM04-BA	0.50^{e}	1.87^{c}	0.07^{fg}	0.53^{abc}	9.43^{h}	14.33^{cdefg}
TZE-Y-DT-STR-C4	1.07^{abcd}	2.27^{abc}	0.27^{abcde}	0.43^{bc}	17.87^{abc}	16.37^{bcdefg}
DORKE SR	0.45^{e}	4.35^{abc}	0.10^{efg}	1.00^{abc}	12.30^{defgh}	16.75^{bcdef}
NYAN03	0.65^{cde}	3.80^{abc}	0.10^{efg}	0.67^{abc}	12.27^{defgh}	20.13^{abc}
TZE-W-DT-STR-C4	1.00^{abcde}	3.35^{abc}	0.23^{bcdef}	0.80^{abc}	15.07^{abcdef}	13.65^{defg}
NYIA03	0.50^{e}	2.17^{abc}	0.13^{g}	0.50^{abc}	14.80^{abcdef}	18.03^{bcde}
NYLA04	0.55^{de}	4.83^{ab}	0.10^{efg}	1.20^{ab}	9.65^{gh}	16.70^{bcdef}
TAAN04	1.40^{ab}	1.77^{c}	0.25^{abcdef}	0.33^{c}	15.65^{abcde}	12.60^{efg}
NYSW03-Y	1.13^{c}	2.77^{abc}	0.27^{abcde}	0.53^{abc}	19.23^{a}	13.13^{efg}
DT-STR-W-C2	0.45^{e}	3.57^{abc}	0.00^{g}	0.83^{abc}	9.70^{gh}	20.03^{abc}
SISF03-0B	0.85^{bcde}	2.03^{abc}	0.20^{cdef}	0.43^{bc}	11.40^{efgh}	15.57^{bcdefg}
KOBN04-R	0.70^{cde}	2.83^{abc}	0.10^{efg}	0.63^{abc}	11.23^{efgh}	17.73^{bcdef}
TAIS03	1.50^{a}	3.30^{abc}	0.25^{abcdef}	0.97^{abc}	10.55^{fgh}	14.43^{cdefg}
CHMA04	0.90^{bcde}	2.70^{abc}	0.30^{d}	0.87^{abc}	13.50^{cdefgh}	19.47^{abcd}
IWD-C3-SYN-F2	1.50^{a}	3.90^{abc}	0.35^{abc}	0.65^{abc}	10.55^{fgh}	10.50^{g}
NYFA04	0.97^{abcde}	3.43^{abc}	0.20^{cdef}	0.67^{abc}	10.83^{fgh}	15.47^{bcdefg}
GH120 DYF/D POP	0.55^{de}	4.45^{abc}	0.10^{efg}	1.10^{abc}	9.40^{h}	18.40^{abcde}
NYFA03	0.93^{bcde}	2.57^{abc}	0.17^{cdefg}	0.67^{abc}	10.83^{fgh}	11.87^{fg}
Mean	0.94	3.08	0.21	0.70	12.86	16.48
SEM	0.22	0.20	0.01	0.05	0.50	0.51

SEM = Standard error of mean; Genotypes having the same letters (vertical direction) are not significantly different at the 5% level of probability

Table 3: Variation in fresh and dry shoot weight of different maize genotypes under normal and water stressed conditions in a pot experiment across the northern Savanna region of Ghana

Genotype	Fresh shoot weight (g)		Dry shoot weight (g)	
	Water- stressed	Normal	Water- stressed	Normal
CHFB04-OB	20.00^{a}	85.90^{a}	2.80^{a}	8.95^{ab}
KPAS04	12.27^{bcdef}	88.45^{a}	2.60^{bcdefg}	10.20^{a}
OKOMASA	10.37^{cdef}	38.93^{bcd}	1.30^{cdefgh}	3.97^{d}
KOBN03-OB	13.73^{abcde}	33.27^{cd}	1.83^{bcde}	3.77^{d}
NYAZ03-Y	9.73^{defg}	28.43^{cd}	1.43^{cdefgh}	3.30^{d}
NYAZ04-W	12.37^{bcdef}	41.10^{bcd}	1.70^{bcdefg}	4.50^{d}
GUMA03-OB	14.07^{abcde}	46.00^{bcd}	1.70^{bcdefg}	4.37^{d}
GBRM04-BA	8.17^{efg}	38.77^{cd}	1.06^{efghi}	4.03^{d}
TZE-Y-DT-STR-C4	11.20^{bcdef}	38.50^{cd}	1.50^{cdefg}	3.90^{d}
DORKE SR	6.67^{fg}	56.35^{bc}	1.00^{fghi}	6.35^{bcd}
NYAN03	9.70^{defg}	53.43^{bcd}	1.30^{cdefgh}	5.53^{cd}
TZE-W-DT-STR-C4	14.17^{abcde}	68.20^{ab}	1.73^{bcdef}	7.95^{abc}
NYIA03	6.50^{fg}	47.40^{bcd}	0.97^{fghi}	4.63^{d}
NYLA04	3.95^{g}	43.47^{bcd}	0.45^{i}	4.57^{d}
TAAN04	16.42^{abc}	25.67^{d}	2.35^{ab}	3.40^{d}
NYSW03-Y	11.73^{bcdef}	44.40^{bcd}	1.47^{cdefgh}	4.97^{cd}
DT-STR-W-C2	7.90^{efg}	55.87^{bc}	0.90^{ghi}	6.07^{bcd}
SISF03-0B	11.52^{bcdef}	45.60^{bcd}	1.50^{cdefg}	4.60^{d}
KOBN04-R	10.20^{cdefg}	43.90^{bcd}	1.20^{defghi}	4.03^{d}
TAIS03	17.35^{ab}	35.90^{cd}	2.05^{abc}	3.73^{d}
CHMA04	14.60^{abcd}	42.70^{bcd}	1.95^{bcd}	4.10^{d}
IWD-C3-SYN-F2	16.50^{abc}	29.00^{cd}	1.95^{bcd}	4.05^{d}
NYFA04	14.00^{abcde}	45.13^{bcd}	1.73^{bcdef}	3.90^{d}
GH120 DYF/D POP	6.15^{fg}	49.40^{bcd}	0.65^{hi}	4.75^{d}
NYFA03	10.47^{cdef}	35.80^{cd}	1.40^{cdefgh}	4.93^{cd}
Mean	11.59	46.46	1.50	4.98
SEM	2.38	2.44	0.27	0.27

SEM = Standard error of mean; Genotypes having the same letters (vertical direction) are not significantly different at the 5% level of probability

Table 4: Variation in days to 50% anthesis, days to 50% pollen shed and days to 50% silking of different maize genotypes under normal and water stressed field conditions during the 2013 cropping season across the northern savanna region of Ghana

Genotype	Days to 50% anthesis		Days to 50% pollen shed		Days to 50% silking	
	Water-stress	Normal	Water-stress	Normal	Water-stress	Normal
CHFB04-OB	56.00^{c}	59.67^{cdefgh}	62.67^{fgh}	68.00^{abcd}	65.67^{defgh}	66.00^{cdefgh}
KPAS04	57.00^{bc}	60.00^{bcdefgh}	62.33^{gh}	68.33^{abc}	64.33^{ghi}	67.00^{abcdef}
OKOMASA	64.00^{a}	64.00^{a}	69.00^{a}	70.67^{a}	72.00^{a}	72.00^{a}
KOBN03-OB	57.00^{bc}	62.00^{abcde}	64.33^{def}	68.67^{abc}	68.33^{bcd}	67.67^{abcdef}
NYAZ03-Y	57.00^{bc}	60.33^{abcdefg}	64.00^{efg}	69.00^{ab}	67.33^{cdef}	68.33^{abcde}
NYAZ04-W	54.00^{d}	57.00^{ghij}	55.67^{j}	63.00^{efgh}	57.67^{j}	62.67^{fghij}
GUMA03-OB	57.00^{bc}	61.67^{abcdef}	65.00^{cde}	70.00^{ab}	67.33^{cdef}	70.00^{abc}
GBRM04-BA	58.00^{b}	62.33^{abcd}	68.33^{ab}	69.67^{ab}	70.67^{ab}	70.00^{abc}
TZE-Y-DT-STR-C4	52.00^{d}	55.00^{ijk}	54.67^{j}	59.33^{hi}	57.00^{j}	58.33^{j}
DORKE SR	57.00^{bc}	59.00^{defgh}	65.00^{cde}	69.00^{ab}	67.33^{cdef}	70.00^{abc}
NYAN03	57.00^{bc}	58.67^{defghi}	64.33^{def}	67.67^{abcd}	67.33^{cdef}	67.00^{abcdef}
TZE-W-DT-STR-C4	52.67^{d}	51.33^{k}	55.67^{j}	59.00^{i}	57.67^{j}	58.00^{j}
NYIA03	57.00^{bc}	57.00^{ghij}	62.00^{hi}	61.67^{fghi}	63.33^{hi}	61.00^{ij}
NYLA04	63.33^{a}	59.00^{defgh}	68.67^{a}	66.33^{bcde}	70.67^{ab}	66.67^{bcdefg}
TAAN04	57.00^{bc}	58.00^{fghi}	65.33^{cde}	66.33^{bcde}	68.00^{bcde}	66.67^{bcdefg}
NYSW03-Y	50.00^{e}	54.00^{jk}	54.33^{j}	61.00^{ghi}	59.33^{j}	58.67^{ij}
DT-STR-W-C2	58.67^{b}	63.67^{ab}	66.67^{bc}	70.00^{ab}	68.00^{bcde}	71.67^{ab}
SISF03-0B	57.00^{bc}	56.33^{hij}	62.00^{hi}	63.00^{efgh}	62.67^{i}	61.67^{ghij}
KOBN04-R	57.00^{bc}	55.00^{jk}	60.33^{i}	64.33^{g}	63.33^{i}	63.67^{efghi}
TAIS03	57.00^{bc}	60.33^{abcdefg}	64.00^{efg}	67.00^{abcd}	66.67^{defg}	67.33^{abcdef}
CHMA04	57.00^{bc}	63.00^{abc}	66.00^{cd}	69.67^{ab}	70.33^{ab}	70.00^{abc}
IWD-C3-SYN-F2	57.00^{bc}	58.33^{fghi}	65.00^{cde}	65.00^{cdef}	70.00^{abc}	64.00^{defgh}
NYFA04	57.00^{bc}	60.33^{abcdefg}	63.00^{fgh}	68.00^{abcd}	65.00^{fghi}	66.67^{bcdefg}
GH120 DYF/D POP	57.00^{bc}	61.33^{abcdef}	64.33^{def}	70.33^{a}	65.33^{efghi}	69.00^{abcd}
NYFA03	57.00^{bc}	63.00^{abc}	65.00^{cde}	70.67^{a}	68.33^{bcd}	68.00^{abcde}
Mean	57.79	59.21	64.89	66.63	66.92	66.08
SEM	0.36	0.43	0.35	0.46	0.44	0.56

Genotypes having the same letters (vertical direction) are not significantly different at the 5% level of probability

Table 5: Variation in Grain yield and drought rating of different maize genotypes under normal and water stressed field conditions during the 2013 cropping season across the northern savanna region of Ghana

Genotypes	Grain yield (tons/ ha)		Drought rating at 10 WAPE
	Water-stress	Normal	Water – stressed plants
CHFB04-OB	0.55^{cdefgh}	4.13^{abcd}	4.67^{ab}
KPAS04	0.67^{bcdefg}	3.39^{cdefgh}	4.33^{abc}
OKOMASA	0.13^{h}	3.01^{efghi}	5.00^{a}
KOBN03-OB	0.71^{bcdef}	3.55^{bcdefg}	4.00^{bcd}
NYAZ03-Y	0.83^{bcde}	4.81^{a}	4.33^{abc}
NYAZ04-W	0.99^{bcd}	2.96^{efghi}	3.33^{de}
GUMA03-OB	0.99^{bcd}	3.89^{abcde}	3.33^{de}
GBRM04-BA	0.93^{bcde}	3.33^{cdefgh}	4.33^{abc}
TZE-Y-DT-STR-C4	0.41^{efgh}	2.88^{fghi}	4.33^{abc}
DORKE SR	0.57^{cdefgh}	2.80^{ghi}	4.33^{abc}
NYAN03	0.96^{bcd}	3.95^{abcdee}	3.67^{cde}
TZE-W-DT-STR-C4	0.77^{bcdef}	2.59^{ghi}	4.00^{bcd}
NYIA03	1.07^{bc}	4.19^{abc}	3.33^{de}
NYLA04	0.61^{bcdefgh}	3.81^{abcdef}	5.00^{a}
TAAN04	0.67^{bcdefg}	4.61^{a}	4.33^{abc}
NYSW03-Y	0.14^{h}	2.77^{ghi}	4.67^{ab}
DT-STR-W-C2	0.27^{gh}	2.32^{i}	4.33^{abc}
SISF03-0B	1.74^{a}	4.08^{abcd}	3.00^{e}
KOBN04-R	0.87^{bcde}	3.57^{bcdefg}	3.67^{cde}
TAIS03	0.59^{bcdefgh}	2.64^{ghi}	4.33^{abc}
CHMA04	1.10^{b}	3.52^{bcdefg}	4.00^{bcd}
IWD-C3-SYN-F2	0.16^{gh}	2.53^{hi}	5.00^{a}
NYFA04	0.94^{bcd}	4.45^{ab}	3.67^{cde}
GH120 DYF/D POP	0.51^{defgh}	2.69^{ghi}	4.67^{ab}
NYFA03	0.62^{bcdefgh}	3.15^{defghi}	4.67^{ab}
Mean	0.71	3.41	4.17
SEM	0.08	0.11	0.59

WAPE, weeks after plant establishment; Genotypes having the same letters (vertical direction) are not significantly different at the 5% level of probability

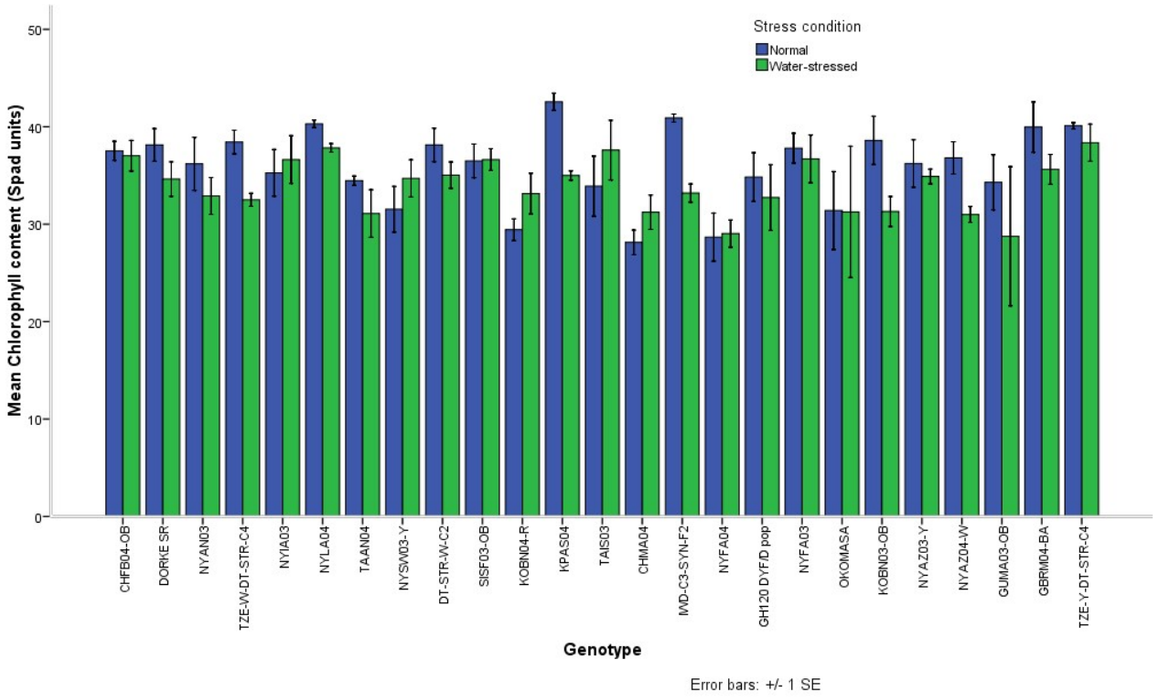

Figure 1: Variation in relative chlorophyll content of the genotypes for the control (normal) and water-stressed treatments; Bars represent standard error of mean; Measurements were made at six weeks after planting

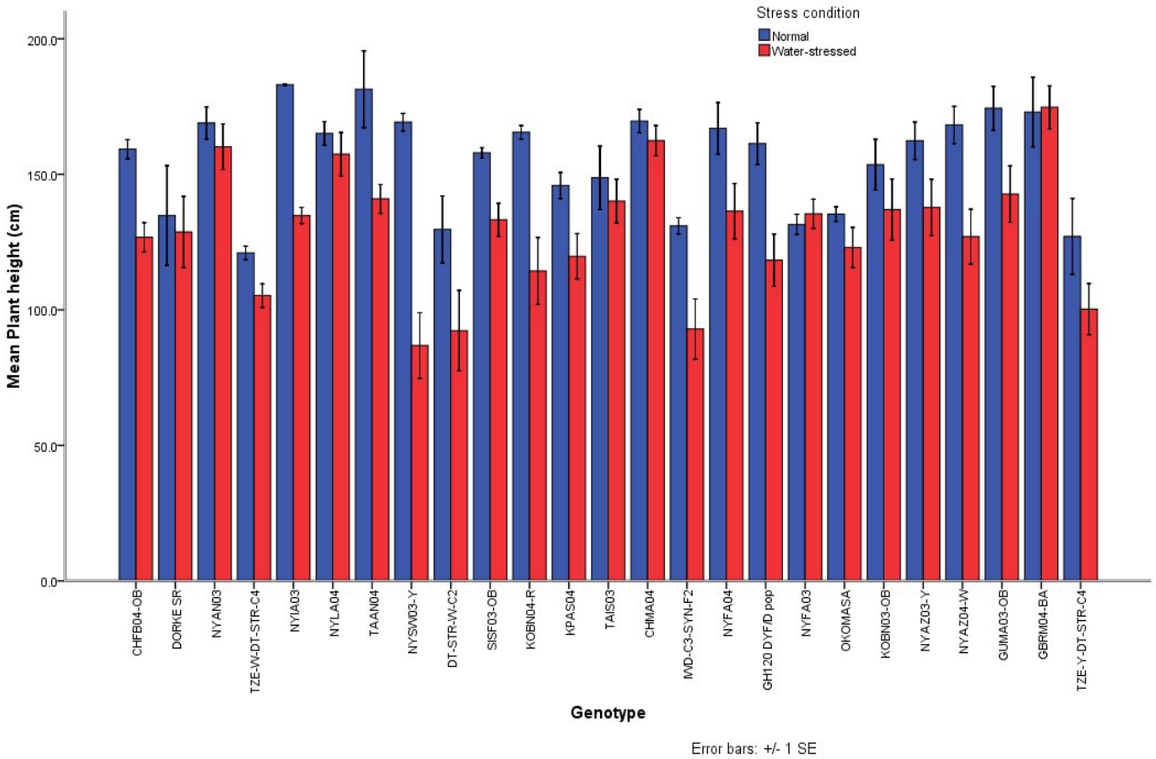

Figure 2: Changes in plant height of the genotypes during screening under field conditions in 2013 cropping season; Bars represent standard error of mean

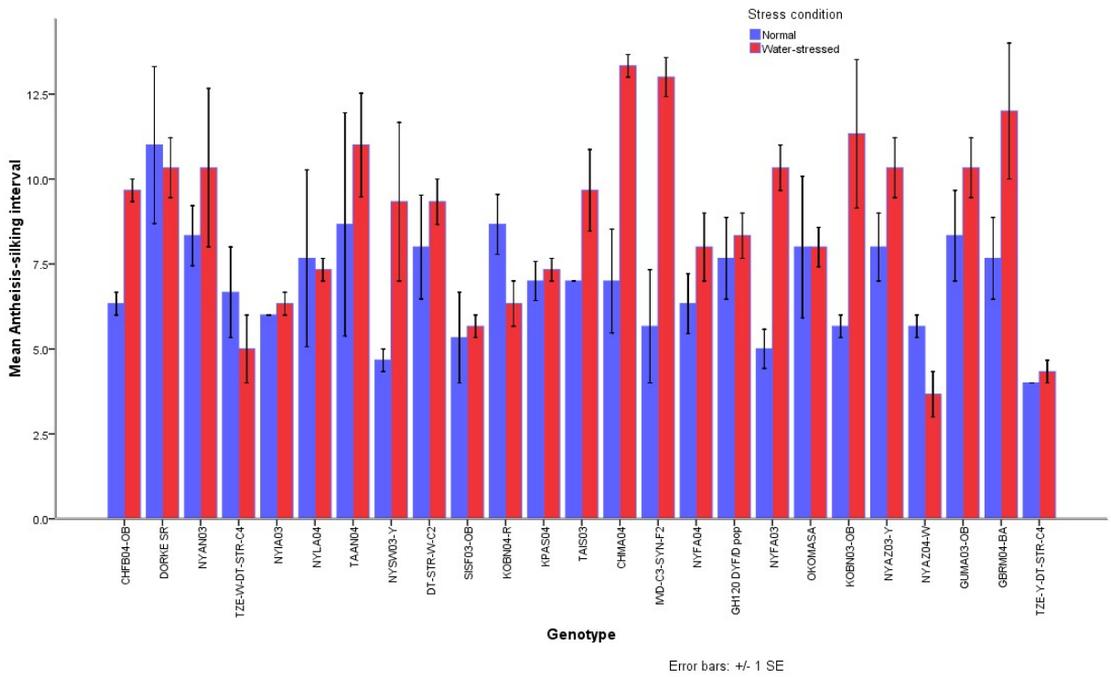

Figure 3: Trends in anthesis-silking interval of genotypes during screening under field conditions in 2013 cropping season; Bars represent standard error of mean

Very significant variations ($P < 0.001$) were also observed in the number of days to silking (Table 4). Among the normal treatments, the genotype OKOMASA recorded the highest number of 72 days, while TZE-W-DT-STR-C4 recorded the least number of 58 days. For the water-stressed treatments, OKOMASA recorded the maximum number of days to 50% silking (72), whilst TZE-Y-DT-STR-C4 recorded the minimum number of days to 50% silking (57) (Table 4).

Silking was non-uniform in the water-stressed genotypes, which confirms the finding of Rowland (1993) that water stress at silking impairs extrusion of silks from the cob husk, causes desiccation of the silks and inhibits pollen tube growth: all resulting in fewer grains per cob.

Yield and yield components

There were highly significant variations ($P < 0.001$) among genotypes for grain yield (Table 5). Among the normal treatments, the genotype NYAZ03-Y recorded the highest grain yield of 4.81 tons/ha, whilst DT-STR-W-C2 recorded the lowest of 2.32 tons/ha. For the water-stressed treatments, SISF03-OB recorded the highest grain yield of 1.74 tons/ha, whilst OKOMASA recorded the least of 0.13 tons/ha (Table 5). There was also a highly significant variation ($P < 0.001$) in grain yield between the normal and water-stressed plants. The relatively high yield of plants that received regular water application (normal) as compared with those under water stress is attributed to lack of water during the grain-filling phase. This is in consonance with the findings of Rowland (1993) that deficits of water at vegetative stage, flowering and reproductive phase can lead to reduction in final yield. Results from the drought rating of water-stressed plants indicates that genotypes IWD-C3-SYN-F2, NYLA04 and OKOMASA are more susceptible to impact by drought, whilst SISF03-OB is least susceptible and more tolerant to drought conditions (Table 5).

There were variations in hundred-grain weight among the genotypes (Figure 1). Values recorded of this trait were

significantly higher ($P < 0.001$) for plants in the normal plots than those subjected to water-stressed conditions. This observation is attributed to the reason given by Rowland (1993) and also Ouattar *et al.* (1987), who attributed the reduction in yield of the water stressed plants to insufficient water in the tissues during the period of flowering and grain-filling, which made it impossible for metabolites such as simple sugars and amino acids to be synthesized

and channeled freely into the grains in adequate quantities for their conversion into the more complex storage compound.

CONCLUSION

Differences exist in the ability of different maize genotypes to tolerate water stressed conditions across the northern savanna region of Ghana. Under the pot experimental conditions, the genotypes SISF03-OB, GUMA03-OB, TAAN04, TAIS03, NYAZ04-W, TZE-Y-DT-STR-C4, KOBN03-OB and NYSW03-Y produced the best performance in terms of the parameters studied. For the field study, the genotypes SISF03, NYIA03, GUMA03-OB, DORKE SR, TZE-W-DT-STR-C4, NYFA04, KOBN04-R, KOBN03-OB and CHMA04 produced the best results for yield and yield related parameters. For high yield under drought conditions across northern Ghana, genotypes SISF03-OB, GUMA03-OB and KOBN03-OB are recommended for cultivation.

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