



## Variation, ranking and component analysis of ten maize populations

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### Abstract

An experiment was conducted in the screen house of the Department of Crop, Soil and Pest Management of the Federal University of Technology, Akure, Nigeria during the 2016/2017 dry season. Drought as a constraint to maize production have caused 24 million tonnes yield loss annually on a global scale, thus the development of maize genotypes that can withstand drought stress at vegetative phase. The objectives of the experiment were to (i) determine the magnitude of genetic variation among ten maize population and the extent of association among them (ii) identify the vegetative traits that could be used in discriminating between drought tolerant and drought susceptible maize genotypes, and (iii) identify the best drought tolerant population (s) to be used as parents in hybridization. The ten maize populations were planted in polythene bags in a split plot experiment laid out in Completely Randomized Design (CRD) with three replications having four drought stresses (1, 2, 3 and 4 weeks of moisture stress) and a control. Data were collected on plant height, root length, number of roots per plant, number of leaves per plant, root weight, biomass and shoot weight. Data obtained were subjected to analysis of variance (ANOVA) and significant means were separated using Tukey Honest Significant Difference. Also, Principal Component Analysis (PCA) was employed to identify the most discriminating characters for the maize populations. Results of the analysis of variance revealed significant variation among the populations for all traits except for emergence rate index, emergence index and Plant height. The PCA identified percentage senescence, root length, number of roots per plant and plant height as the four most discriminating traits contributing most to variation for drought tolerance of the maize populations at vegetative phase. From this study, Rank Summation Index revealed DT-Y-Syn / 4 and TZL Comp.1-WC<sub>6</sub>/white DT STR (Syn) -DFC as the best and worst populations for drought tolerance.

**Keywords:** correlation, maize populations, principal component analysis and variation

### Introduction

Maize (*Zea mays* L) is a member of the grass family *Poaceae*, a classification it shares with many other important crops, including wheat, rice, oats, sorghum, barley, and sugarcane (Buckler and Stevens, 2005) <sup>[11]</sup>. It is the world most widely grown cereal after wheat and rice (Morris *et al.*, 1999) <sup>[28]</sup>. It is also the primary staple food for most developing countries. It has a remarkable place among cereals as it has great yield potential and attained the leading position among cereals based on its productivity as well as production (Keshin *et al.*, 2005) <sup>[23]</sup>; it is cultivated over more diverse environmental and geographical range than other cereal crops indicating its physiological efficiency and wide adaptation. Maize production has become very popular and the crop is widely grown in many countries of the world (Taiwo *et al.*, 2011) <sup>[36]</sup>. Maize being a short duration crop can be grown successfully twice in a year and it fits well in Nigeria's cropping system as it is well adapted to the country's climatic conditions.

Advances in maize breeding and production have played significant roles on the lives of many people in the world. Every part of the plant has an economic value as the leaves, grain, stalk, tassels are used to produce hundreds of food and non-food products (Ihejirika *et al.*, 2007) <sup>[20]</sup>. Maize is used as food for man in different forms. In many parts of Africa, green (fresh) maize is boiled or roasted on its cob

and served as a snack. Popcorn is also a popular snack. It is also processed and prepared in various forms depending on the country and it is an important source of carbohydrate, protein, iron, Vitamin B and minerals (Abdulrahman and Kolawole, 2006) <sup>[2]</sup>. Maize is an important ingredient of feed for most livestock. Yellow maize is preferred in feed formulation for livestock as it gives a yellow colour to poultry egg yolks and animal fat (IITA, 2009) <sup>[21]</sup>. Maize can serve as raw material for many industrial products such as syrup, alcohol, filler for plastics, packing materials, insulating materials, chemicals, explosives, paint, paste, abrasives, dyes, insecticides, pharmaceuticals, organic acids, solvents, antifreeze, soaps, starch e.t.c (Duane *et al.*, 2011) <sup>[14]</sup>.

In spite of its usefulness and high yield potential, maize production is being faced with many constraints which hinder its optimal production. These constraints may be biotic (pests, diseases, weeds e.t.c) or abiotic (Drought, heat, nutrient deficiencies e.t.c). Among the abiotic constraints, drought is the most devastating and it has a harsh effect on all living things. Drought is a meteorological condition in which the amount of water available through rainfall and or irrigation is insufficient to meet the crop needs for optimal growth and development (Allah *et al.*, 2016) <sup>[4]</sup>. It is characterized by extreme water deficiency accompanied by desiccating wind and an extremely low rainfall. High

temperature and low humidity is also a feature of drought making the environment inhospitable to man, animal and plants. As climate change intensifies, drought conditions in Africa sparks fears of a new cycle of food shortages. This is because majority of the resource-poor farming communities in Africa still depend on rain-fed agriculture (Olaoye, 1999)<sup>[32]</sup>. According to Enabor (1985)<sup>[16]</sup>, the economic implications of drought worldwide are: (i) severe food shortage with its associated spiralling of food prices, (ii) extensive crop failure leading to severe food shortage and possibly famine in the affected areas, (iii) destruction of export crops which ruins the export economy and high losses of foreign exchange earning to the country, (iv) forced emigration of victims to more favourable environments in search of food which may be of different culture and organization. This affects unity of families and causes conflicts in some cases as well as refugee problems. Other effects are increased livestock death which reduces in reduced supply of animal protein and losses to livestock owners.

Drought is a major challenge to maize production globally causing up to 24 million tonnes of yield loss annually (Cairns *et al.*, 2013)<sup>[5]</sup>. Ninety percent of maize is grown under rain-fed conditions and 25% of which suffers from drought (Slingo *et al.*, 2005; Beddington, 2010)<sup>[35, 10]</sup>. Drought can occur in any stage of maize growth (i.e. seedling, vegetative, pre-anthesis and post-anthesis). Drought impact is more at the onset of the reproductive stage which can cause 100% yield loss if accompanied with high temperature (Anami *et al.*, 2009)<sup>[6]</sup>. Similarly, if drought occurs during the vegetative stage, it causes a reduction in leaves size, number of kernel and the plant (Anami *et al.*, 2009)<sup>[6]</sup>.

Assessment of drought tolerance at seedling stage is necessary to predict a good crop stand at maturity (Mock and McNeill, 1979; Koscielniak and Dubert, 1985; Qayyum, *et al.*, 2012)<sup>[24, 33]</sup>. This is because if drought occurs at this stage, it can reduce crop establishment and may lead to zero yield or complete crop failure (Edmeades *et al.*, 1994; Akinwale *et al.*, 2016)<sup>[9, 7]</sup>. Most researches on drought tolerance in maize have been concentrated at the flowering and grain-filling periods (Banziger and Lafitte, 1997; Banziger *et al.*, 1999; Badu-Apraku *et al.*, 2011)<sup>[15, 7]</sup> without considering how the genotypes would respond if drought occurred at the vegetative stage (Akinwale *et al.*, 2016)<sup>[7]</sup>. Development of maize drought-tolerant genotypes that can withstand drought stress at the vegetative stage of maize is one of the approaches to reduce the adverse effects of drought as a result of climate change. This can only be done when there are enough genetic variation at the vegetative stage and suitable traits have been identified to distinguish between drought tolerant and drought sensitive genotypes at the vegetative stage.

### Objectives

1. To determine the magnitude of genetic variation among ten maize population and the extent of association among them

2. To identify the vegetative traits that could be used in discriminating between drought tolerant and drought susceptible maize genotypes, and
3. To identify the best drought tolerant population(s) to be used as parents in hybridization.

### Materials and Methods

The experiment was carried out in the screen house of the Department of Crop, Soil and Pest Management of the Federal University of Technology, Akure, located in rainforest South-Western region of Nigeria during the 2016/2017 dry season. Ten maize populations were obtained from the International Institute of Tropical Agriculture, Ibadan, Oyo state, Nigeria in 2016. The descriptions of genotypes are as presented in Table 1.

Ten seeds of each population were planted in a polythene bag at a depth of 2cm. The polythene bags were filled with topsoil collected from the Teaching and Research Farm of the Federal University of Technology, Akure. The experiment was a split plot arranged in completely randomized design with three replications. Moisture stress was in the main plot while maize population was in the sub plot. The experiment had four water stress regimes (1, 2, 3 and 4 weeks of moisture stress) and a control. Adequate watering was done for 7 days in order to ensure good germinating environment, after which water stress was introduced by withdrawing watering. In the first block, watering was stopped 7 days after planting (7 DAP) while in the second block watering was stopped 14 DAP. The watering of the third block was stopped 21 DAP while the fourth block watering was stopped 35 DAP. The control received water throughout the period of the experiment i.e. no water stress. Data were collected on a weekly basis on each watering regime. The experiment was terminated after 42 DAP. Data was collected on Plant height (cm), Number of leaves, Root length (cm), Number of roots, Plant biomass (g). Data collected were used to calculate estimated value for Number of wilted leaves, Number of un-wilted leaves, Percentage senescence, Emergence Index, emergence percentage, emergence rate index, Speed of germination and Seedling vigour.

The data obtained on each parameter assessed on the basis of sampled plants were averaged and the mean values obtained were used for statistical analysis. Data collected were subjected to analysis of variance (ANOVA) using Minitab version 17. Means were separated using Tukey Honest Significant Difference ( $P = 0.05$ ). A Rank Summation Index (RSI) method of Mulumba and Mock (1978) was used to rank the populations based on their drought tolerance performance. To obtain the RSI, populations were first ranked at vegetative stages (1= best, 10 = poorest). Ranks of the drought tolerance traits at the vegetative stage were summed up to generate overall performance of each population. Thus, the lower the RSI of any population, the greater is its drought tolerance. The principal component analysis and cluster analysis were done using Past 3.18 software (Hammer *et al.*, 2001)<sup>[19]</sup>.

**Table 1:** Description of Ten maize populations.

S/N	Name	Genotypes as used in Figures	Drought conditions	Sources
1	DSTR - WC1	G3	Tolerant	IITA
2	TZL COMP.1-WC6/white DT STR (Syn) - DFC	G9	Tolerant	IITA
3	DT- STR - W SYN/2	G4	Tolerant	IITA

4	TZL COMP.4 DT	G10	Tolerant	IITA
5	DT - W- SYN II	G5	Tolerant	IITA
6	DT-Y- SYN/4	G6	Tolerant	IITA
7	2009 TZM-SUSC	G2	Susceptible	IITA
8	POP 66. SR/ARC.9/SUWAN 1-SR	G8	Local check	IITA
9	DT STR-Y SYN 2	G7	Tolerant	IITA
10	1WDC 3-SYN 2/white DT STR SYN DT C1	G1	Tolerant	IITA

## Results

Genotypic variation among the populations for seedling traits shows significant differences among varieties for all traits evaluated except for emergence index, emergence rate index and plant height (Appendix 1). The performance of the ten maize populations in respect of their seedling traits are presented in Table 2. There was significant difference in the means of the populations except for plant height and emergence index. The highest seedling vigour (11.12) was recorded for IWDC 3 -SYN 2/ white DT STR- SYN DT C1 while DT-STR-W-SYN 2 (6.06) had the least mean. 2009 TZM-SUSC had the highest speed of emergence of 7.07 while DT-STR-W SYN 2 had the least mean of 2.89. TZL Comp.1-WC<sub>6</sub>/white DT STR (SYN)-DFC (99.33) and DT-STR-W SYN2 (53.33) had the highest and least mean for emergence percentage, respectively. Emergence rate index ranged from 0.20 for TZL COMP.1-WC<sub>6</sub>/white DTSTR (Syn) - DFC to 0.34 for DT-STR-W SYN/2.

Correlation coefficient of seedling traits for the maize populations is as presented in Table 3. Positive and significant correlation was observed between plant height and seedling vigour (0.57). Emergence percentage had positive and significant correlation with all traits except emergence index and plant height. Speed of emergence had a positive and significant correlation with emergence index (0.86). Seedling vigour (0.62) and emergence percentage had negative but significant correlation with emergence rate index (-0.53).

Principal Component Analysis was used to identify character that contribute to drought tolerance, result shows that the first three principal component axes with eigen values of 90.51, 5.56 and 2.13 respectively, jointly accounted for 98.20% of the total variation among the populations studied (Table 4). The first principal component axis (PC1) accounted for 90.51% of the total variation. It was positively loaded with percentage senescence (0.96) and negatively loaded with plant height (-0.23). PC2 was positively loaded with percentage senescence (0.23) and plant height (0.95). PC3 was negatively loaded with number of roots (-0.49) and positively loaded with root length (0.82). The arithmetic sign of the coefficient in the eigen value of the PCA is irrelevant.

## Discussion

In crop improvement, the knowledge of genetic variability for traits within the genotypes determines the success of the breeding programme. The variation observed in seedling traits of the ten populations namely plant height, emergence percentage, seedling vigour and speed of emergence suggests that improvement through selection for these traits could be effective. The variation observed among the populations for the evaluated seedling traits might be due to the diverse genetic backgrounds of the maize populations. Genetic variation in seedling traits have been reported in

different crops like maize, cowpea, rice and fluted pumpkin by Fakorede and Ojo (1981) <sup>[17]</sup>, Ajala *et al.* (2003) <sup>[3]</sup>, Okelola *et al.* (2007) <sup>[31]</sup> and Fayeun *et al.* (2016) <sup>[18]</sup>, respectively. Among the populations, POP 66.SR /ACR.91 SUWAN 1-SR, IWDC 3 -SYN 2/ white DT STR SYN DT C 1 had the highest mean for plant height and seedling vigour respectively. Therefore these populations can be selected as parents for hybridization or used directly as variety for improved seedling traits and consequently to improve yield. High correlation between some seedling traits (seedling vigour and plant height) and yield maize have been reported in maize by Mann (1994) <sup>[25]</sup> and Jawaharlal *et al.* (2011) <sup>[22]</sup>.

Adebisi (2008) <sup>[3]</sup> pointed out that strong positive correlation suggests that selection for one trait could be used to indirectly select for another character but this could be difficult during selection if desirable and undesirable traits are linked together. The positive and strong correlation between emergence percentage and seedling vigour, speed of emergence and emergence rate index implies that selection for high emergence percentage will lead to improvement of these characters.

Uniform seedling emergence and their vigorous establishment can ensure good plant population and final yield (Copeland and McDonald, 2001; Tekrony *et al.*, 2005; Shirin *et al.*, 2008) <sup>[13, 37]</sup>.

This is important because it influences field emergence, seedling establishment and subsequent performance of the resulting plant (Moreno-Martinez *et al.*, 1998; Abbasian *et al.*, 2013) <sup>[27, 11]</sup>.

Seedling vigour is related with better yield performance (Gregory *et al.*, 1992) which gives the seedling some comparative advantage to overcome some environmental stress. This implies that higher number of root is not desirable trait when screening for drought tolerance at seedling stages.

Principal component analysis as a multivariate statistical tool had been used by many researchers to establish the differential response of genotypes to drought stress. Among these researchers are Bouchabke *et al.* (2008), Liming *et al.* (2015) and Kwabena *et al.* (2016) who performed experiment on *Arabidopsis thaliana*, *Zea mays* and *Phaseolus vulgaris* respectively. The PCA revealed that plant height, percentage senescence count, number of roots and root length were the most important traits that contribute to variation for drought tolerance among the maize populations evaluated. Thus they can be regarded as traits of interest. Similar result was reported by Obeng-Bio *et al.* (2011) <sup>[7]</sup> and Sabiel *et al.* (2014) <sup>[34]</sup> who found plant height and percentage senescence as drought tolerance determinants in maize. Also, Akinwale *et al.* (2016) <sup>[4]</sup> have reported root length and number of roots as drought stress determinants at vegetative stage in maize.

Configurations of the 10 maize populations along the first two principal component axes are shown in Figure 1. The ordination of the populations on axes 1 and 2 (Figure 1)

grouped populations into three clusters based on characters associated with PC1 and PC2. Cluster III consists of the best populations (G8, G9, and G10) whereas cluster II consists of the poorest populations. Cluster I comprise of the intermediate ones.

Based on these four traits, PCA and Cluster analysis grouped the ten populations into three groups. The group could be regarded as deternotic group in which different inbred lines can be developed for further improvement programmes.

**Table 2:** Performance of the 10 maize populations evaluated for seedling traits

Populations	Plant height (cm)	Emergence rate index	Seedling vigour	Emergence index	Speed of emergence	Emergence percentage (%)
DSTR-WC1	11.67a	0.25ab	9.68a	21.00a	5.90ab	83.33a
IWDC 3 -SYN 2/ white DT STR SYN DT C 1	11.50a	0.21bc	11.12a	20.53a	6.57ab	96.67a
TZL Comp.1-WC <sub>6</sub> /white DT STR (SYN) –DFC	10.43a	0.20bc	9.70a	19.83a	6.66ab	99.33a
DT-STR-W SYN 2	11.20a	0.34a	6.06b	17.93a	2.89b	53.33b
TZL Comp.4 DT	11.67a	0.22b	10.86a	20.70a	6.49ab	93.33a
DT-W-SYN II	9.93a	0.22b	8.64ab	19.30a	5.24ab	86.67a
DT-Y-SYN / 4	11.53a	0.23ab	10.38a	20.57a	6.33ab	90.00a
2009 TZM-SUSC	12.00a	0.23ab	10.80a	20.67a	7.07a	90.00a
POP 66.SR /ACR.91 SUWAN 1-SR	12.27a	0.22b	11.04a	19.70a	5.62ab	90.00a
DT STR-Y-SYN 2	11.77a	0.23ab	9.44ab	18.27a	4.55ab	80.00a

Note: mean with the same alphabet are not significantly different from each other

**Table 3:** Correlation coefficient among the seedling traits in the maize populations

Seedling characters	Emergence percentage (%)	Seedling vigour	Speed of emergence	Emergence index	Emergence rate index
Plant height (cm)	0.08	0.57**	0.08	0.04	0.11
Emergence percentage (%)		0.86**	0.69**	0.33	0.70**
Seedling vigour			0.62**	0.31	-0.53*
Speed of emergence				0.86**	-0.12
Emergence index					0.28

\*Significant at probability level of 0.05 and \*\*significant at probability level of 0.01

**Table 4:** Eigen vectors for ten characters of the first three principal components used in the ordination.

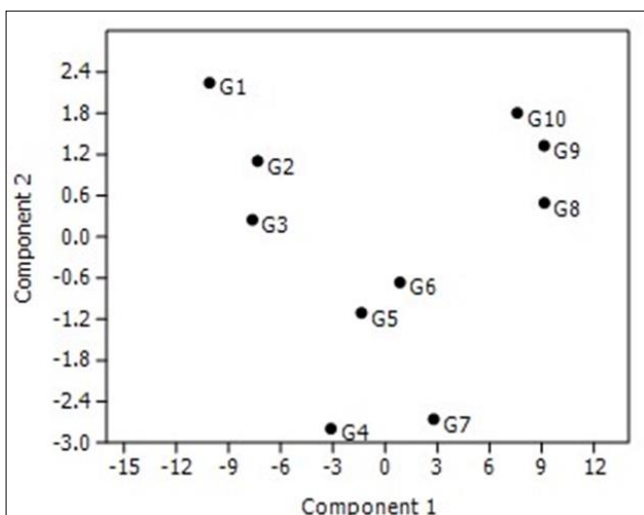
Character	PC 1	PC2	PC3
Number of unwilted leaves	-0.08	0.01	-0.06
Number of roots	-0.04	0.18	-0.49
Root length (cm)	-0.11	-0.10	0.82
Number of leaves	-0.03	0.05	-0.15
Number of wilted leaves	0.05	0.04	-0.09
Plant height(cm)	-0.23	0.95	0.17
Percentage Senescence (%)	0.96	0.23	0.10
Root dry weight(g)	0.00	-0.00	0.01
Biomass(g)	0.04	0.01	0.04
Shoot weight(g)	0.03	0.02	0.04
Eigen value	50.94	3.12	1.20
Percentage variance (%)	90.51	5.56	2.13
Cumulative variance	90.51	96.06	98.19

**Drought performance of the maize populations using Rank Summation Index**

The rank summation index of population based on PCA identified drought tolerance traits are presented in Table 5. DT-Y-Syn / 4 had the best performance among the population with a mean of 2.4. It was followed by DT STR-Y-Syn 2 with a mean of 4.0. TZL Comp.1-WC<sub>6</sub>/white DT STR (Syn) –DFC had the poorest performance with a mean of 7.8. This was followed by DT-STR-W SYN/2with a mean of 7.2. Thus, DT-Y-Syn / 4 was the best among the populations while TZL Comp.1-WC<sub>6</sub>/white DT STR (Syn) -DFC was the worse of the populations. From the Rank summation index, DT-Y-Syn / 4, DT STR-Y-Syn 2, 2009 TZM-Susc., DSTR-WC1, TZL Comp.4 DT were identified as the best populations because they had the lowest overall mean for PCA identified drought tolerance traits thus, it can be used as a reference for population evaluation with emphasis on the desired trait.

**Conclusion**

In conclusion, drought ranks second after soil infertility as the most limiting factor of crop production which occurs through insufficient rainfall and poor distribution. Water deficit has a negative impact on all levels of growth and root development of maize. Its duration also has an impact on the growth and productivity of maize. Plants have developed numerous adaptive mechanisms for better growth under drought conditions such as modification of the root system, osmotic adjustments, stomatal regulation, chemical production and accumulation. The efficiency with which a plant utilizes these mechanisms and the understanding of how it affects performance can be used to improve plant tolerance to drought stress. The study revealed some



**Fig 1:** Configuration of ten populations under axes 1 and 2

important agronomic characters (percentage senescence, plant height, number of roots and root length) that can be

used in pre-anthesis maize breeding for drought tolerance.

**Table 5:** Rank of populations based on PCA identified drought tolerance traits

Populations	Plant height (cm)	Percentage Senescence (%)	Number of Roots	Root length (cm)	Plant biomass (g)	Grand sum	mean rank	rank
DSTR-WC1	22.03 (7)	68.59(1)	11.87(4)	14.40 (10)	7.70 (2)	24	4.8	4
IWDC 3 -Syn 2/ white DT STR Syn DT C 1	20.84 (10)	65.52(2)	9.84 (8)	17.66 (6)	3.30 (9)	35	7.0	8
TZL Comp.1-WC6/white DT STR (Syn) –DFC	21.97 (8)	57.74(8)	10.51 (7)	16.25 (8)	3.46 (8)	39	7.8	10
DT-STR-W SYN 2	24.80(5)	63.58(4)	9.00 (10)	16.31 (7)	3.18(10)	36	7.2	9
TZL Comp.4 DT	26.17 (2)	56.82(9)	10.91 (5)	17.72 (5)	5.39 (4)	25	5.0	5
DT-W-Syn II	24.02 (6)	64.48(3)	9.80 (9)	15.65 (9)	4.20 (5)	32	6.4	7
DT-Y-Syn / 4	27.30 (1)	59.89(6)	13.47 (2)	18.98 (2)	10.49 (1)	12	2.4	1
2009 TZM-Susc	24.83 (4)	54.15(10)	13.67 (1)	20.00 (1)	4.04 (6)	22	4.4	3
POP 66. SR /ACR.91 Suwan 1-SR	21.83 (9)	60.79(5)	10.73 (6)	18.95 (3)	3.60 (7)	30	6.0	6
DT STR-Y-Syn 2	25.72 (3)	59.32(7)	12.11 (3)	17.76 (4)	6.38 (3)	20	4.0	2

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