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Preliminary evaluation of drought tolerance traits in selected maize germplasm using cultivar Performance Index (PI) analysis at seedling stage

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ABSTRACT: Drought in varying frequencies and intensities remain an emerging major constraint limiting the potential of arable crop production across the continents. The knowledge and understanding of effective but less cumbersome methods in determining the response of genotypes to drought stress can aid researchers easily in identifying and selecting potential parents for drought tolerance hybrid development breeding programmes. This study is aimed at assessing genotype drought tolerance levels of selected maize germplasm and their suitability for selection as parental materials for developing drought-tolerant hybrids. This study was carried out in the screen house of the Forestry Research Institute of Nigeria, Federal College of Forestry, Jos. Four seedlings of 24 maize genotypes of different genetic backgrounds were raised in pots arranged in a randomized complete block design with three replicates. The experiment was adequately watered for the first seven days and thereafter watering stopped. The plants were observed for 45 days and some simple seedling water use response parameters were measured as drought tolerance indicators. Collected data were subjected to Analysis of Variance (ANOVA) and Correlation Analysis. Genotype response performance ranking was done using the statistical procedure in cultivar Performance Index (PI) methods. Analysis of variance for plant seedling height (cm), leaf area (m^2), plant collar girth (cm), number of leaves, number of dead/shed leaves, fresh shoot weight (g), dried shoot weight (g), fresh root weight (g), dried root weight (g), seedling primary root length (cm), root volume (cm^2) and seedling traits showed significant differences across all the traits. Performance Index (PI) analysis results made the selection of high performing genotypes such as PVA-SYN-F0, MARA AURE-Y (DAMAGU) 1, KAF-22, TZM-BOKKOS, KAF-16, MARA-AURE-W (DAMAGU), KIERKIER, TZM-BOKOS, and KAF-16. These can be used in breeding programmes to create potential plant ideotypes with better adaptation for drought-stressed habitats with possible high yield potentials in the field.

Keywords: Draught, lines, Performance Index (PI), ranking, selection, tolerance level.

INTRODUCTION

Maize also known as corn *(Zea mays* L), is the world's most widely grown cereal crop ranking third to rice and wheat in terms of production in the world (FAO, 2012). The African Development Bank (AFDB) (2015) reported that sixteen of the world's 22 countries where maize accounts for the largest percentage of calorie intake in the national diet are in Africa. Maize provides about half of the calories and protein consumed in Eastern and Southern Africa and one-fifth of the calories and protein consumed in West Africa. Maize provides food and economic security to an estimated 208 million people in Sub-Saharan Africa (Grote et al., 2021). The crop has been projected to become the most important crop by 2030 (Salvi et al., 2007). Maize is a C4 plant and is physiologically adapted to diverse environments making it unmatched by any other cereal

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crop (Izhar and Chakraborty, 2013). According to the Information and communication support for agricultural growth in Nigeria (2017), Nigeria presently produces about 8 million tons annually with yield per hectare ranging between 2000 to 6000 kg/ha depending on the agro-ecological zone. Despite the volume of improvement research and extensive heterosis exploitation in maize, there seems to be a persistence of such limiting factors as low seed yield, poor resistance to biotic and abiotic stressors, poor adaptation to various agro-ecologies, and low tolerance to draughts. High yield losses has been reported to be due to: drought ,the devastating effects of parasitic weeds, tolerance to low nitrogen, salinity, high and low temperatures, and soil nutrient deficiencies (Banziger et al., 2000; Olaokojo and Olaoye,2005; Badu-Aprakuet al.,2010; Badu-aprakuet al., 2011; Ogunniyan and Olakojo, 2015).

The incidences of global climate change has increased the occurrence and severity of drought episodes due to higher evapotranspiration and rising temperatures. Among all listed stressors affecting maize productivity, drought stresses have been known to affect yield through more different mechanisms across the whole life cycle of the maize plant (Leach et al., 2011; Li et al., 2015). One of the key recent breeding strategies for crops such as maize is to identify new varieties with higher grain yields and improved nitrogen- and water-use efficiencies. An increasing body of evidence indicates that the engineering of root system architecture has the potential to support a second green revolution targeting crop performance under suboptimal water and nutrient supply. Due to its importance for many plant functions, Root System Architecture (RSA) has become a topic on its own in many research communities (Orman-Ligeza et al., 2014). Any genetic progress for resistance to abiotic stressors will be lasting one, indicating that RSA engineering will have profound implications for improving water- and nutrient use efficiency of crops and enhancing productivity under abiotic stressors or in an suboptimal conditions (de Dorlodot et al., 2007; Lynch, 2007).

Roots are the first organs to perceive and respond to drought but below-ground phenotyping screening of the root systems is rarely undertaken, particularly under field conditions. The distribution of roots, particularly those that can penetrate deeper into the soil, plays a crucial role in determining the ability of plants to capture key resources such as water and mobile nutrients like nitrate. Root architecture, therefore, has a profound effect on the growth and yield of crop plants (Fenta et al., 2014). However, relatively few studies have been performed to date using root parameters to select for enhanced nitrogen use efficiency (NUE) or improved water use efficiency (WUE) in modern crop varieties (Fenta *et al.,* 2014). Finally, RSA determines largely the extent of the contacts and interactions between the plant and the rhizosphere (Li *et al.,* 2015). Under drought stress, plants aim to lessen the impact of the lack of water by reducing the transpiration rate and by enhancing the efficiency of water acquisition from the soil. 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 root system not only supports the above-ground organs of the plant but also plays a crucial role in obtaining water by accessing sources far down in the soil profile (Trachsel *et al.,* 2010). The root system is therefore generally considered as the most important organ concerning improving crop adaptation to water stress (Vadez, 2014). Maize responds to drought stress by redirecting root growth and dry matter accumulation away from the shoot to the root (Sharp *et al*., 2004; Ribaut *et al*., 2009). These modifications result in the sustained growth of the root and inhibit the growth of the shoot in the face of decreased water potential (Ober *et al.,* 2005; Ober and Sharp, 2007; Li *et al.,* 2015).

Drought can damage a crop field at any time throughout the growing season. The fate of seedlings will determine the structure and dynamics of most plant populations according to the “stress gradient hypothesis” (Kitajima and Fenner, 2000; De La Cruz *et al*., 2008; Li *et al*., 2015). Root morphology is a poorly studied maize character due to the difficulties of making direct measurements under the soil and also of observing or removing roots of plants grown under agronomic conditions. Thus, phenotypical evaluation at the seedling stage is regarded as an attractive approach because it is a high throughput and low-cost method that saves space and time (Meeks *et al.,* 2013). This approach has been successfully used to develop drought-tolerant varieties in cowpea (Singh and Matsui 2002), cotton (Longenberger *et al.,* 2006), wheat (Tomar and Kumar, 2004), and maize (Ruta *et al.,* 2010; Meeks *et al.,* 2013; Pace *et al.,* 2014). Another advantage of using seedling drought screens, where young seedlings undergo cycles of water stress in the greenhouse, is that phenotypical variations caused by experimental errors can be controlled better because the plants are much more uniform at the early seeding stage, compared to other periods of plant development (Wang *et al*., 2015). Genetic improvement to producing deep -rooted plants is considered an important strategy for improving water capture and yield stability (Kondo *et al.,* 2003).

Efforts are needed towards the development of hybrids with high yield potential to increase maize production. All plant breeding programmes involving selection and hybridization are aimed at concentrating the different useful genes existing in a pooled genetic diversity to create the much desired superior F_1 plant ideotype (Mustafa *et al.,* 2014). Some common reliable statistical analysis methods to distinguish best performing varieties rely on available mean separation for the significant test such as: Least significant difference (LSD), Duncan's multiple range test (DMRT), t-test and Z-test, etc., are used by researchers to aid in selecting the best genotypes from varieties trials. The information on the nature of the targeted trait whether qualitative or complex quantitative polygenically controlled and its interaction with environmental conditions are important (Nadagoud, 2008; Reddy and Jabeen, 2016; Mesenbet *et al.,* 2016). Likewise, for creating selection indices for genetic improvement of any of these qualities of interest, information on the type of association and related correlations obtained through correlation analysis is required (Mesenbet *et al*., 2016). Although, these are established statistical procedure but somewhat cumbersome when compared to cultivars or genotypes performance index (PI) techniques of rating which give a p-value information that is not normally made obvious by LSD in determining genotypes for selection, especially if the number of varieties are many, thereby making visual discrimination difficult (Fasoulas 1983; Bodunde, 2002; Yisa *et al.,* 2018). Therefore, this study was carried out to evaluate the response of 24 different genotypes with diverse genetic backgrounds to drought stress imposed at the seedling phase and the relationship among the seedlings traits to select the best performed desirable genotypes for drought tolerance at the early growth stage.

MATERIALS AND METHODS

Study location

This study was carried out in the screen house of the Forestry Research Institute of Nigeria- Federal College of Forestry, Jos, located in the Northern Guinea Savanna ecological zone of Nigeria on 09°56'N, 08°53'E at an altitude of 1,217M above sea level.

Screen-house-evaluation

Six seeds each of the 24 different maize genotypes of different genetic backgrounds were sown in the uniformly cut polyvinyl chloride (PVC) pipes as pots of 45 cm long and 10 cm diameter. Each pot was filled with a 4.0 kg of loamy soil textural class as shown in Table 1 and adequately irrigated to its field capacity daily, for three days before seeds was sowed. After seedling emergence, seedlings was thinned to four seedlings per pot and arranged in a complete randomized design with three replications. The experiment was adequately watered at the rate of 0.6 litres per pot daily for the first 10 days, and thereafter watering stopped. The plants were observed for 45 days. After watering was ceased, fortnightly observations and data collecting on growth and morphological features, as well as seedling water use response parameters measured as drought tolerance markers, commenced. Number of leaves (NOL), the number of dead/shed leaves (NODL/NOSL) were taken fortnightly, while seedling height (SHT), leaf area (LA), using procedures described by Mckee (1964), plant collar girth (PCG) were recorded at the 45th day. The below-ground measurement was equally commenced following modification of the procedure described by Harrington *et al*. (1994) and Obeng-Bio *et al*. (2011). Each pot containing the seedlings with the ball of soil was carefully lowered into a 2000 litres capacity bowl filled with water to remove the roots carefully which were washed free of sand, each was transferred to another 25 litre capacity container of water to ensure total removal of sand. The roots were cut off from the shoot at the cotyledonary node. Observation and data were recorded on the length of the primary root (LPR in cm) using a meter rule. Seedling fresh shoot weight (g), fresh root weight (g), dry shoot weight (g), and dry root weight (g) were measured using the sensitive digital Metler weighing balance. Dry weights were obtained by subjecting plant tissue samples to oven-drying at 80°C until a constant weight was achieved. Moisture content was determined by subtracting the dry weight of the sample from its fresh weight. The seedling aspect in Table 2 was scored on a scale of 1 to 9 (Akinwale *et al*., 2017).

Statistical analysis

All data collected were subjected to analysis of variance (ANOVA) using Crop-Stat Analysis Package Software to test for any significant effect of the treatments on traits observed on the experimental entries. Means separation was carried out using the Least Significant Difference (LSD) at 0.05 level of probability and the Duncan multiple range test (DMRT). Correlation analyses were performed to reveal any existing interrelationships among traits and identify traits that could be reliably used to select for drought tolerance at this stage. The performance responses of the 24 genotypes for root volume (RV), length of primary root (LPR), and seedling aspect were selected as key indicators for drought tolerance (Lynch and Ho, 2005). The means of these traits were subject to the cultivar performance index (PI) analysis as described in Echekwu and Showemimo (2001), Fasoulas (1983), Bodunde (2002) and Yisa *et al*. (2018). The mean values for these traits for the various genotypes were arranged in descending order of magnitude. The LSD values obtained from the analysis of variance for each trait were subtracted from the first mean and compared to the remaining variety means. The number of variety means that were less than this value and the number of varieties that were significantly inferior to the first variety mean. This number was designated as 'm'. The procedure was repeated thereafter for the second and subsequent variety means. Eventually, a series of 'm' values were obtained for each trait. The individual 'm' values were used to calculate the cultivar performance index (PI) as defined by Fasoulas (1983):

$$PI = \frac{m}{n-1} x\ 100$$

Where: m = number of significantly inferior varieties (genotypes/cultivars) and n = number of varieties tested.

Table 1. Seedling aspects scores.

Scale	Symptoms	Visibility on plants
1	No visible symptom of stress	vigorous plants, no wilting, no dead leaves, no chlorosis, no height reduction, and unrolled turgid leaves
2	Very mild symptom of stress	vigorous plants, no wilting, no dead leaves, no chlorosis, very slight leaf rolling
3	Mild symptom of stress	vigorous plants, no wilting, no dead leaves, no chlorosis, leaf rim start to roll
4	Mild symptom of stress	vigorous plants, no wilting, no dead leaves, slight chlorosis, the leaf has the shape of a V
5	Moderate symptom of stress	vigorous plants, no wilting, 10% dead leaves, slight chlorosis, rolled leaf rim covers part of the leaf blade
6	Susceptible plants	less vigorous plants, moderate reversible wilting, 25% dead leaves, severe chlorosis, the leaf is rolled like that of an onion
7	Highly susceptible	severe irreversible wilting with 50% dead leaves
8	Highly susceptible	severe irreversible wilting with 75% dead leaves, 75% death of seedlings
9	Very highly susceptible	total collapse or 100% death of seedling, dried leaves, and stem

Note: Seedling aspect rating scales of 1-5 indicate different levels of tolerance of the seedlings while scales of 6-9 indicate levels of susceptibility of the seedlings.

Table 2. The Physico-chemical property of the soil used at the start of the experiment

Parameter	Value
Particle size distribution (%)	
Coarse sand	14.2
Fine sand	66.1
Clay	3.6
Silt	16.4
Textural class	Loamy
pH(H20)	6.47
pH(KCL)	5.04
Organic Carbon (%)	0.81
Total Nitrogen (%)	0.08
Total Phosphorus (mg/kg)	6.2
Base saturation (%)	48.6
Organic matter (%)	1.54
Exchangeable cations (c mol / kg)	
K	0.11
Mg	1.9
Ca	2.7
Na	0.06
Al	1.4
H	2.2
CEC	8.35
Zn (ppm)	6.27
Fe (ppm)	5.11
Cu (ppm)	3.69
Mn (ppm)	1.78
S (ppm)	0.69

Soil Analysis Values were obtained from a predetermine potting mixture ratio.

RESULTS

Genetic variation among genotypes

Results of the analysis of variance of seedling traits investigated revealed significant differences among the twenty-four genotypes (Table 3).

Correlation analysis

Results of the correlation analysis for all the traits studied (Table 4) revealed significant positive association for seedling number of leaves with plant leaf area index (r = 0.47), plant collar girth association significantly with leaf area index, and fresh shoot weight (r = 0.47; r = 0.51), the leaf area index correlated significantly with plant seedling height (r =0.62), fresh shoot weight (0.59), dry shoot weight (0.47), fresh root weight (0.50) and dry root weight (0.49). Plant height was significantly associated with fresh shoot weight (r = 0.51), dry shoot weight, and dry root weight (r = 0.75, 0.76) respectively. Root volume correlated significantly with fresh root weight (r = 0.63). Dry root weight was positively and significantly correlated with fresh shoot weight (r = 0.55) and dry shoot weight (r = 0.92). Fresh root weight correlated significantly with plant seedling height (r = 0.67), plant collar girth (r = 0.40), fresh shoot weight (r = 0.61) and dry shoot weight (r = 0.59). The fresh shoot weight correlated significantly with dry root biomass weight (r = 0.51).

Genotype performance index and ranking

The outputs of the performance index (PI) ranking analyses integrating some roots-related variables and the genotype aspect at the seedling stage for the genotypes

Table 3. Mean squares for analysis of variance of selected maize genotypes evaluated under imposed drought stress at seedling stage at the screen house of the Forestry Research Institute of Nigeria- Federal College of Forestry, Jos.

S/N	Traits	Mean square	Replications	Error
	Source of variation	Treatments		
	DF	23	2	46
1	PSH	370.437**	0.348888	6.0006
2	LA	5008.32*	21.6064	13.7101
3	PCG	21.4470**	0.530416	0.5226
4	NOL	7.30203**	0.70875	1.0173
5	NSL	2.69305**	0.722222	1.1045
6	FSW	1369.39**	5.00334	15.8097
7	DSW	9.21710**	0.463576	0.2603
8	FRW	84.9521**	1.65375	1.3024
9	DRW	9.09618**	0.19625	0.3999
10	LPR	125.009**	9.25167	4.3298
11	RV	50.7470**	2.23625	0.6615
12	SA	3.06280*	0.138889	0.0139

Note: *, ** = Significant at 5% and 1% probability levels respectively. Number of Leaves (NOL), Number of Dead /Shade Leaves (NODL/NOSL,) Plant Seedling Height (PSH), Leaf Area (LA), Plant Collar Girth (PCG), Seedling Aspect (SA); Root Volume (RV); Length of Primary Root (LPR); Dry Root Weight (DRW); Fresh Root Weight (FRW); Fresh Shoot Weight (FSWT); Dry Root Weight (DSWT); Leaf Area (LA).

Table 4. Correlation coefficient for twenty-four genotypes evaluated in the screen house under imposed drought stress at the seedling stage at the Forestry Research Institute of Nigeria- Federal College of Forestry, Jos.

Traits	PSH	LA	PCG	NOL	NSL	FSW	DSW	FRW	DRW	LPR	RV	SA
PSH	1	0.615157*	0.358833*	0.182501	-0.08404	0.508626*	0.745756*	0.665591*	0.758711*	0.414266*	0.377049*	0.088814
LA	0.615157*	1	0.473067*	0.468829*	-0.08445	0.58352*	0.473913*	0.50294*	0.487175*	0.197052	0.267556	-0.12194
PCG	0.358833*	0.473067*	1	0.322396	0.193452	0.507219*	0.252375	0.400176*	0.250896	0.079572	0.019053	0.036112
NOL	0.182501	0.468829*	0.322396	1	0.196023	0.439971*	0.211727	0.270241	0.179572	0.269424	0.058382	-0.05646
NSL	-0.08404	-0.08445	0.193452	0.196023	1	0.212134	0.119351	0.044011	0.112013	-0.02162	-0.02162	0.353271
FSW	0.508626*	0.58352	0.507219*	0.439971*	0.212134	1	0.544644*	0.611633*	0.505032*	0.277774	0.279483	0.146134
DSW	0.745756*	0.473913*	0.252375	0.211727	0.119351	0.544644*	1	0.594907*	0.918029*	0.328577	0.352009*	0.207727
FRW	0.665591*	0.50294*	0.400176*	0.270241	0.044011	0.611633*	0.594907*	1	0.567372*	0.397143*	0.630514*	-0.02434
DRW	0.758711*	0.487175*	0.250896	0.179572	0.112013	0.505032*	0.918029*	0.567372*	1	0.294838	0.355651*	0.208249
LPR	0.414266	0.197052	0.079572	0.269424	-0.02162	0.277774	0.328577	0.397143*	0.294838	1	0.162412	-0.21796
RV	0.377049	0.267556	0.019053	0.058382	-0.00806	0.279483	0.352009*	0.630514*	0.355651*	0.162412	1	0.095768
SA	0.088814	-0.12194	0.036112	-0.05646	0.353271*	0.146134	0.207727	-0.02434	0.208249	-0.21796	0.095768	1

*Significant at p = 0.05 levels of probability. Number of Leaf (NOL), Number of Dead /Shade Leaf (NODL/NOSL,) Plant Seedling Height (PSH), Leaf Area (LA), Plant Collar Girth (PCG), Seedling Aspect (SA); Root Volume (RV); Length of Primary Root (LPR); Dry Root Weight (DRW); Fresh Root Weight (FRW); Fresh Shoot Weight (FSWT); Dry Shoot Weight (DSWT); Leaf Area (LA).

Table 5. Performance Index (PI) ranking analysis for twenty-four genotypes evaluated in the screen house under imposed drought stress according to the genotype primary root length at the seedling stage at the Forestry Research Institute of Nigeria- Federal College of Forestry Jos.

S/N	Genotypes	DMRT	M	PI (%)	Ranking
1	KIERKIER	46.0[a]	21	91.30	1
2	TZPB-SRW	44.0[a]	21	91.30	1
3	MARA AURE -W(GUJUBA)-2	44.0[a]	21	91.30	1
4	TZM –FOB-L	38.0[b]	17	73.91	4
5	MARA AURE –Y(DAMAGU)-1	36.0[bc]	12	52.17	5
6	KAF -16	36.0[bc]	12	52.17	5
7	MARA AURE –W(POTISKUM)	35.0[bcd]	10	43.48	7
8	SAMMAZ 52	34.0[cde]	4	17.39	8
9	TZM-BOKOS –L	34.0[cde]	4	17.39	8
10	MARA AURE-Y(GUJUBA)-1	33.0[cde]	4	17.39	8
11	KAF-3	33.0[cde]	4	17.39	8
12	KAF-4	32.8[cde]	4	17.39	8
13	MARA AURE –W (DAMAGU)	32.0[de]	4	17.39	8
14	KAF-15	32.0[de]	4	17.39	8
15	TZE-WDTSTR C4	31.0[ef]	3	13.04	15
16	TZM -129	31.0[ef]	3	13.04	15
17	PVA –SYN –F0	31.0[ef]	3	13.04	15
18	KAF -21	31.0[ef]	3	13.04	15
19	KAF-22	31.0[ef]	3	13.04	15
20	PVA –SYN-13	30.7[ef]	3	13.04	15
21	SAMMAZ 32	28.0[g]	2	8.70	21
22	OBA SUPER 11 F2	27.0[g]	2	8.70	21
23	SAMMAZ 24	22.0[h]	1	4.35	23
24	SUWAN-1-SR-Y	16.0i	0	0.00	24
	LSD at 5% probability	3.42			

Means with the same letter are not statistically significant at p = 0.05 levels of probability.

are in Tables 5 to 7. The results showed that genotypes KIERKIER, TZPB-SRW, and MARA AURE-W (GUJUBA)-2 recorded high-performance indices of 91.3% each and ranked highest for genotypes with the highest means of primary root length (Table 5). Genotypes PVA-SYN-F0, MARA AURE-Y (DAMAGU)-1, and KAF-22 recorded high-performance index percentages of 100, 91.30, and 91.30% respectively, and ranked of 1, 2, and 2 respectively. The performance index and ranking for plant aspect traits response at the seedling stage recorded high scores for genotype KIERKIER, TZM-BOKKOS, KAF-16, and MARA-AURE-W (DAMAGU) with 86.96% each and ranked 1.

DISCUSSION

The primary objectives of this investigation was to find out the response of the 24 different genotypes with a diverse genetic background to imposed drought stress at the seedling stage using the cultivar performance index (PI) as an analysis option in evaluating drought tolerance response traits as indicators, to present a simple, quick, visual discrimination and detailed information over other basic conventional analysis methods, in selecting the best performing genotypes (Echekwu and Showemimo, 2001; Bodunde, 2002; Yisa *et al.,*2018). When used as indicators, some plant physiological and morphological traits can reflect plant drought resistance more concisely and accurately at the seedling stage (Cantao *et al*., 2008; Liu *et al*., 2017).

The analysis of variance (ANOVA) revealed significant differences at p=0.05% probability for all the traits evaluated. This indicated that the genotypes responded differently to the traits evaluated. The performance of genotypes PVA-SYN-F0, MARA AURE-Y (DAMAGU)-1, KAF-22,TZM-BOKOS, KAF-16, and MARA-AURE-W (DAMAGU) concerning the selected root traits results using the performance index (PI) analysis in this study indicates their potential efficiency in resource acquisition

Table 6. Performance index (PI) rankings analysis for twenty-four genotypes evaluated in the screenhouse under imposed drought stress according to genotype root volume at the seedling stage at the Forestry Research Institute of Nigeria- Federal College of Forestry Jos.

S/N	Genotypes	DMRT	M	PI (%)	Ranking
1	PVA –SYN –F0	21.9[a]	23	100.00	1
2	MARA AURE –Y(DAMAGU)-1	12.0[b]	21	91.30	2
3	KAF-22	12.0[b]	21	91.30	2
4	MARA AURE-W (GUJUBA)-2	10.0[c]	18	78.26	4
5	KAF -21	10.0[c]	18	78.26	4
6	KIERKIER	10.0[c]	18	78.26	4
7	KAF -16	8.4[d]	13	56.52	7
8	TZE-WDTSTR C4	8.0[d]	12	52.17	8
9	PVA –SYN-13	8.0[d]	12	52.17	8
10	KAF-15	8.0[d]	12	52.17	8
11	SAMMAZ 24	7.3[de]	8	34.78	11
12	MARA AURE-Y(GUJUBA)-1	7.0[de]	8	34.78	11
13	MARA AURE –W (DAMAGU)	6.4[e]	8	34.78	11
14	TZPB-SRW	6.0[ef]	7	30.43	14
15	MARA AURE –W(POTISKUM)	6.0[ef]	7	30.43	14
16	KAF-4	6.0[ef]	7	30.43	14
17	OBA SUPER 11 F2	4.8[fg]	2	8.70	17
18	KAF-3	4.2[g]	1	4.35	18
19	TZM-BOKOS –L	4.2[g]	1	4.35	18
20	SAMMAZ 32	4.0[g]	1	4.35	18
21	TZM -129	4.0[g]	1	4.35	18
22	TZM –FOB-L	4.0[g]	1	4.35	18
23	SUWAN-1-SR-Y	3.4[g]	1	4.35	18
24	SAMMAZ 52	2.0[h]	0	0.00	24
	LSD at 5% probability	1.34			

Means with the same letter are not statistically significant at p = 0.05 levels of probability.

particularly, water and nutrients in the field. This result supports the findings of Hurd (1974) who suggested in his study that plant response at the seedling stage is a reflector of its potential to produce higher root volume and longer root length under a field. Similarly, Obeng-bio *et al*. (2011) in a drought stress-imposed study reported that root growth at the seedling stage may therefore be useful in predicting root growth under drought stress at later growth stages in the field.

The plant aspect could be considered as a physiological indicator of plant water-use efficiency (WUE) which is an indicator of water consumption and drought adaptability of a plant (Martin *et al.,* 1999; Ray *et al.,* 1999; Liu *et al.,* 2017). High WUE is a mechanism of plant adaptation to water deficit and an important characteristic of plant response to an arid environment (Jaleel *et al.,* 2008; Sun *et al.,* 2008). The results obtained confirmed the findings of Obeng-bio *et al.* (2011), who reported similarly, that leaf rolling indices greater than 3 might be susceptible to drought because at that stage the leaf rim begins to roll to cover part of the leaf blade. Similarly, any genotype that shows plant aspect index beyond 3 might not exhibit full photosynthetic capacity and might further have impaired dry matter production as partitioning of photosynthates assimilates from the leaves (source) to the grain (sink) might be considerably reduced (Bänziger *et al.,* 2000; Obeng-bio *et al*., 2011).

The relationships among seedling traits were done to identify traits for measuring drought tolerance at the seedling phase among the genotypes. The correlation analysis showed that the plant aspect had a positive but non-significant relationship with other traits but showed a strong association to the number of dead/shade leaves. However, Moser (2004), Vadex (2014), and Akinwale *et al.,* (2017) reported that the seedling aspect is identified as an important trait in the seedling stage. This indicates that the seedling aspect could serve singly as a selection criterion for drought tolerance at the seedling stage or in

Table 7. Performance Index (PI) ranking analysis for twenty-four genotypes evaluated in the screen house under imposed drought stress according to genotype aspect at the seedling stage at the Forestry Research Institute of Nigeria- Federal College of Forestry, Jos.

S/N	Genotypes	DMRT	M	PI (%)	Ranking
1	KIERKIER	2.0^e	20	86.96	1
2	TZM-BOKOS	2.0^e	20	86.96	1
3	KAF-16	2.0^e	20	86.96	1
4	MARA-AURE-W (DAMAGU)	2.0^e	20	86.96	1
5	SAMMA- 52	2.0^e	14	60.87	5
6	TZM-FOBUR	3.0^d	14	60.87	5
7	KAF-4	3.0^d	14	60.87	5
8	PVA-SYN -10	3.0^d	14	60.87	5
9	PVA-SYN-13	3.0^d	14	60.87	5
10	OBA SUPER II F2	3.0^d	14	60.87	5
11	TZM-129	3.0^d	5	21.74	11
12	TZPB-SRW	3.0^d	5	21.74	11
13	SAMMAZ-24	3.0^d	5	21.74	11
14	MARA-AURE-Y (DAMAGU)	3.3^c	5	21.74	11
15	KAF-15	4.0^b	5	21.74	11
16	MARA-AURE -W(POTISKUM)	4.0^b	5	21.74	11
17	MARA-AURE-W (GUJUBA)-2	4.0^b	5	21.74	11
18	TZE-WDSTR C4	4.0^b	5	21.74	11
19	SUWAN-1-SR-Y	4.0^b	5	21.74	11
20	SAMMAZ -32	4.0^b	0	0	24
21	KAF-22	5.0^a	0	0	24
22	KAF- 21	5.0^a	0	0	24
23	KAF-3	5.0^a	0	0	24
24	MARA-AURE	5.0^a	0	0	24
	LSD at 5% probability	**0.19**			

Means with the same letter are not statistically significantly different at 5% probability.

combination with other traits in a selection index. Root length had a significant relationship with average fresh and dry root weight. It has been reported earlier that under drought stress, roots elongate in search of water for survival and that deeper and more profuse root systems could tap extra water from the soil profile and alleviate drought effects while shoots are reduced to conserve moisture (Vadez, 2014). Thus, roots traits have also been considered as a major avenue to improve crop adaptation to water limitations at the seedling stage.

Nadir *et al.* (2019) reported that plants respond to water shortages by closing leaf stomata to prevent transpiration, which is followed by a decline in metabolism, which results in a slowdown in plant growth, and enables the establishment of an adapted root system. In drought conditions, any decrease in leaf cell turgor pressure caused by a decrease in leaf water content resulted in a decrease in leaf area growth. As a result, CO^2 absorption by stomata and non-stomata was lowered, and the photosynthetic rate was slowed. Although drought lowered leaf area expansion and hence photosynthesis rate. Nadir *et al.* (2019) revealed that the process is not necessarily damaging because some cereal genotypes of rice have been found to still yield appreciably in such conditions. The wide range of average plant aspect scores recorded among the genotypes under the imposed drought stress indicates high variation. Genotypes KIERKIER, TZM-BOKKOS, KAF-16, and MARA-AURE-W (DAMAGU) performance index scores demonstrate the genotypes' high water use efficiency by maintaining their leaves relatively turgid despite the low soil moisture content. This result supports the findings of Obeng-bio *et al*. (2011) that genotypes with low leaf rolling scores of less than 2 might have high adaptive potentials for conserving water for longer periods under limited soil moisture conditions.

Conclusion and recommendations

Water and nutrient acquisition efficiency of crops could be improved by selection of genotype with the high-performance response for traits that are physiological and morphological indicators of adaptive potentials for drought tolerance in arid habitat or under inadequate soil moisture conditions. The study validated cultivar performance index (PI) analysis methods for the selection of best-performing genotypes in any traits of interest in a crop improvement programme.

The genotypes PVA-SYN-F0, MARA AURE-Y (DAMAGU)-1, KAF-22, TZM-BOKOS, KAF-16, MARA-AURE-W (DAMAGU), KIERKIER, TZM-BOKKOS and KAF-16, might be used as potential parents pool to select from in crop improvement programme for developing drought tolerance lines.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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