Original Research Article

Water Use Efficiency of Maize Genotypes of Different Maturity Groups at Seedling and Grain-filling Growth Stages in a Rainforest Location.

ABSTRACT

Aims (delete): The objectives of this study were to evaluate maize genotypes of different maturity groups for seedling and grain filling water use efficiency and determine relationship that exist between the water use efficiency traits and yield of different maize maturity groups.
Study design: Sixteen maize genotypes were planted in Randomized Complete Block Design in three replicates for emergence, vegetative, water use efficiency traits at the seedling and grain-filling growth stages and yield.
Place and Duration of Study: The sixteen maize genotypes of different maturity groups were evaluated during the early and late cropping seasons of 2016 at the Obafemi Awolowo University Teaching and Research Farm,Country name
Methodology: Data collected were subjected to Analysis of Variance (ANOVA), correlation analysis among water use efficiency traits and yield for each of the maturity groups.
Results: There was no significant difference among the genotypes within each maturity groups for water use efficiency at seedling and grain filling growth stages.
The late maturity group of maize used more water at the seedling growth stage than the other maturity groups in the early season of this study while in the late season, the early and extra-early maturity groups used more water than the other maturity groups. Increase in emergence percentage, reduction in speed of germination, and minimal days to complete germination increased water use efficiency at the seedling stage only during the early cropping season.
Efficiency of water usage at the seedling growth stage was more among the late and intermediate maturing groups than the extra-early and early maturing groups in the early season while in the late season, the extra-early and early maturing groups used water more efficiently than the late and Intermediate maturing groups
Conclusion: Maturity group played a significant role in the expression and manifestation of water use efficiency traits under different environmental conditions.

Keywords: maize, maturity groups, water-use efficiency, seedling growth stage, grain filling growth stage.

1. INTRODUCTION

Maize is a cereal crop that is more extensively distributed globally than any other cereal crops because of its wide adaptability to range of climates. It was also reported that maize is the most widely-grown staple food crop in sub-Saharan Africa (SSA) occupying more than 33 million ha each year [1]. Multi-purpose uses of maize have made it a popular and most widely cultivated crop after wheat and rice in the whole world. This is so because maize contributes about 34 - 36 % of the average daily calorie intake [2-4]. Maize is used for producing alcohol and nonalcoholic drinks. The stem serves as an important source of bio-

fuel [5-7]. It is estimated that maize demand in Sub-Saharan Africa would exceed 52 million tons in 2020 [8]. Despite an increased area of land which has been dedicated to cultivate maize since the mid-2000s, production per hectare in the developing countries is still low (1.3 t/ha) compared to the 8.6 t/ha in developed countries [9].
In most crops, the variation in biomass accumulation and yield production is influenced by the crop's tolerance to water stress, drought, and the efficiency with which the maize crop uses available soil water for growth. This led to the concept of Water Use Efficiency which was broadly defined as the measure of the crop production per unit of water used, irrespective of water source, expressed in units per weight of water depth per unit area, and it can also be explained as the ratio of crop yield over applied water. According to Jensen [10], efficiency has been defined as the ability to produce desired effect with minimum effort, expenses, and waste. Several reports had shown the relationship between water use efficiency and maize production [11-14]. A linear relationship was reported by [15-18,13] between grain yield and water use efficiency in maize, that is, increase in water use efficiency will lead to an increase in grain yield and vice versa, while a curvi-linear relationship was established between water use efficiency and grain yield of maize as reported by Yazar et al. [16].
Maize has different responses to water deficit according to its developmental stages [19, 20]. Drought stress is particularly damaging to grain yield if it occurs early in the growing season (plant establishment), at flowering and during mid to late grain filling [21]. The most critical period for water stress in maize is between 10-14 days before and after flowering, with reduction of 2-3 times more when water deficit coincides with flowering compared with other growing stages [22].

Different maturity groups of maize can be used to rescue shortage of maize supply, to ensure adequate all year round cropping in both seasons, and to close down the gap of high demand for maize. Oluwaranti *et al.* [23] reported that, different maturity groups of maize have different quality that makes them acceptable as a variety of maize. As reported by Shaibu *et al,* [24] each maturity group of maize also has its unique advantages and disadvantages with respect to climatic conditions. Drought tolerant maize of different maturity groups has been developed by maize breeders but there is little or no information on how water usage at the seedling and grain filling growth stages of the maize plant are being influenced by their different maturity groups. Therefore, the aim of this study was to evaluate the variations that exist among the genotypes within different maturity group for water use efficiency traits at the seedling and grain filling growth stages and determine the relationship between the maturity groups and efficiency of water usage at the seedling and grain filling growth stages in a rainforest location

2. MATERIAL AND METHODS

2.1 Data Collection

Sixteen drought-tolerant maize varieties, consisting of four varieties each of Extra early, Early, Intermediate and Late maturity groups obtained from the Maize Breeding Programme of International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria were used for the study.

The field experiments were carried out at Obafemi Awolowo University Teaching and Research Farm (T&RF), country name Ile-Ife (latitude 7°25´ N, and longitude 4°39´E), Nigeria, during the early and late cropping seasons of 2016. The experiment was laid out in a randomized complete block design with three (3) replicates. Plots were six rows; 5m long each, with intra and inter-row spacing of 0.5m and 0.75m, respectively.

2.2 Data Collection:

Emergence counts were taken on 5, 7, and 9 days after planting (DAP) to obtain emergence percentage. Data on fresh weight (FWT) of the maize plants commenced nine DAP and continued at five days interval to 39 DAP. Fresh weight of five ears per plot was taken 60 DAP at five days interval till 90 DAP for extra-early and early maturity groups and started 65DAP till 95 DAP for intermediate and late maturity groups. Dry weight (DWT) of the collected maize plants was determined in the laboratory by oven drying at 80^0C to constant weight. Water stored (WSTD) was obtained from the difference between Fresh and Dry weights of the samples. Water used for evapotranspiration was obtained from the product of Potential Evapotranspiration (PET) of the research field and Single Crop Coefficient, (Kc)**,** where (Kc) for maize = 0.35 (FAO 1998). Weather data on the potential evapotranspiration (PET) of the field was obtained from the Automatic Weather station located at the Teaching and Research Farm, OAU, Ile-Ife. Cumulative Water Used was obtained from the addition of the water stored with the water used for Evapotranspiration by the crop at seedling and grain filling stages. Water Use Efficiency (WUE) for each maize variety was estimated from dry weight of the sample and cumulative water used (Water Use Efficiency (WUE) = DWT/ CWU). Seedling Growth Rate (SDGR) and the Grain Filling Growth Rate (GFGR)**;** which measures the rate of dry matter production per Unit of time measures as g/day was obtained by regression method with this linear regression model:

W = a + bt

Where,

W = dry weight per plant:

t = time in DAP

a = intercept of the regression model and

b = regression coefficient which measures the growth rate (GR).

2.3 Statistical Analyses

Data collected from the field experiments were subjected to statistical analysis of variance (ANOVA) using SAS package version 9.0 of statistical analysis (SAS, 2002). The differences among treatment means were separated using Least Significant Difference (LSD) at 0.05 level of probability. Pearson correlation analysis between water use efficiency traits and yield of the different maturity groups of maize were also carried out.

3. RESULTS

Mean square values from combined analysis of variance due to season was highly significant (P = 0.01) for emergence percentage, seedling and grain-filling water used, seedling and grain-filling dry weights, water use efficiency at seedling and grain-filling growth stages, growth rates at the seedling and grain-filling stages and grain yield (Table 1). Highly significant (P = 0.01) maturity effects were obtained on emergence percent, seedling and grain-filling water used, seedling dry weight, seedling growth rate and grain yield (Table 1). Highly significant (P = 0.01) interaction of the season by maturity group was observed on seedling water used, seedling dry weight, water use efficiency and growth rate at the seedling stage. Significant (P = 0.05) interaction of the season by maturity group were also observed on grain-filling dry weight, water use efficiency and growth rate at the grain-filling growth stage and grain yield. (Table 1). The coefficients of variability (CVs) were generally high for emergence, seedling water used, dry weights of the seedling and the filled grains, water use efficiency at the grain filling growth stage, growth rates at the seedling and grain-filling growth stages and grain yield and rather low for water use efficiency at the seedling stage and water used at the grain-filling growth stage. The coefficients of determination (R^2) obtained from the model for the water use efficiency traits at the seedling and grain-filling growth stages were generally high which ranged from 68% to 87%, which indicated that the model was highly reliable (Table 1). It was observed from the results of the evaluation of water use efficiency traits and yield, that there were significantly higher means recorded for most traits in the early copping season compared to the late cropping season of this study except for seedling water used, water use efficiency at the seedling growth stage, growth rate at the grain-filling growth stage and grain yield in which higher values were recorded in the late season (Table 2).

Differences among the means of different maturity groups of maize evaluated for water use efficiency traits, dry matter accumulated at seedling and grain fillings stages and grain yield were obtained during the early and late cropping seasons of 2016 (Table 3). The late maturity group of maize used more water at the seedling growth stage than the other maturity groups in the early season of this study while in the late season, the early and extra-early maturity groups used more water than the other maturity groups. In the early cropping season, the late and intermediate maturity groups had the largest seedling dry weight and the least dry weight obtained in the early and extra-early maturity groups while in the late season, the early and extra-early maturity groups had the largest dry weights with the late and intermediate having the least dry weights (Table 3).

Efficiency of water usage at the seedling growth stage was more among the late and intermediate maturing groups than the extra-early and early maturing groups in the early season while in the late season, the extra-early and early maturing groups used water more efficiently than the late and Intermediate maturing groups (Table 3). The intermediate and late maturing groups had more dry weight of filled grains than the early and extra-early maturity groups in the early season while there were no significant differences among the four maturity groups for the dry weight of the filled grain in the late season of this study (Table 3). Likewise, this trend of no significant difference among the four maturity groups in the late season for grain-filling dry weight was also obtained for the water use efficiency at the grain filling growth stage while the Late and intermediate maturity groups used water more efficiently than the extra-early and early maturity groups in the early season (Table 3). The seedling growth rate of the late maturity group was observed to be higher than the other maturity groups in the early cropping season while in the late season, highest growth rate was observed among the early maturity group followed by the extra-early maturity group with the late maturity group having the lowest seedling growth rate in the late season of this study (Table 3). There were no significant differences among the four maturity groups for grain-filling growth rate in the late season while in the early season, the intermediate and late maturity groups had the highest growth rate at the grain-filling growth stage than the early and extra-early maturity groups (Table 3). There were no significant differences in the grain yield among the four maturity groups during the early season of this study while the early maturity group had the highest yield with the intermediate maturity group having the least in the late season of this study (Table 3).

Table 1: Mean squares from combined analysis of variance for water use efficiency traits of maize of different maturity groups at seedling and grain filling growth stages and grain yield during the early and late cropping seasons of 2016 at the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife, Nigeria**.**

TRAITS	**REP (d.f.=2)**	**SEASON (d.f.=1)**	**MATGRP (d.f.=3)**	**V(MATGRP) (d.f.=12)**	**S*V(MATGRP) (d.f.=12)**	**SEA.*MTGRP (d.f.=62)**	**ERROR**	**CV**	**R^2**
E%	194.43	14412.44**	5222.25**	505.44	126.77	110.08	721.90	43.78	0.46
SDWUSD	1033.41	94077.46**	20840.20**	1205.50	2379.89	56807.01**	2706.52	35.83	0.68
SDDWT(g)	31.16	3768.16**	368.27**	16.72	34.65	687.71**	28.95	43.67	0.81
SDWUE	0.0001	0.0735**	0.0006*	0.0002	0.0003	0.0023**	0.0002	19.51	0.87
GFWUSD	1050.99	8180.32**	3181.41**	416.83	383.29	133.13	558.93	16.07	0.46
GFDWT(g)	831.88	82354.74**	364.89	348.46	618.99	1526.27*	535.20	43.27	0.75
GFWUE	0.05	3.44**	0.02	0.02	0.03	0.08*	0.02	40.87	0.77
SDGR	0.64	74.20**	6.97**	0.30	0.59	13.91**	0.58	42.19	0.81
GFGR	11.62	2365.72**	9.77	19.82	23.23	41.10*	14.95	48.39	0.77
GYLD	2.96	27.78**	5.77**	0.82	1.16	3.88*	1.22	67.22	0.53

*, ** Significant at 0.05 and 0.01 levels of probability respectively;

Table 2: Emergence, Water use efficiency traits and grain yield of the maize genotypes of different maturity groups evaluated during the early and late cropping seasons of 2016 at the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife, Nigeria**.**

Corresponding author: Email: XYZ@ABC.COM

SEASONS	E%	SDWUSD	SDDWT	SDWUE	GFWUSED	GFDWT	GFWUE	SDGR	GFGR	GYLD
EARLY	73.62	113.88	18.59	0.05	156.33	82.76	0.55	0.92	3.03	1.11
LATE	49.12	176.49	6.06	0.10	137.87	24.18	0.17	2.8	12.95	2.18
$LSD_{0.05}$	10.96	21.28	2.20	0.01	9.65	9.45	0.06	0.31	1.58	0.45

E%: emergence percentage; SDWUS: seedling water used; SDDWT: seedling dry weight; WUE: water use efficiency; GFWUSED: grain filling water used; GFDWT: grain filling dry weight; SDGR: seedling growth rate; GFGR: grain filling growth rate. LSD: least significant difference
1

Correlation coefficients among grain yield and water use efficiency traits at the seedling and grain-filling growth stages among the extra-early, early, intermediate and late maturing groups during the early and late cropping seasons of 2016 are presented in Tables 4 and 5 respectively. In the early season, the seedling dry weight was positively correlated with grain yield among the early and late maturity groups (P = 0.01). Water used at the grain filling growth stage was observed to be positively correlated with grain yield among the early maturity group (P = 0.01). Positive correlations were also obtained between grain-filling dry weight and grain yield among the early, intermediate and late maturity groups (P = 0.01) (Table 4). In the early season of this study, Water used and dry weight at the seedling growth stage were positively correlated with emergence percent among the extra-early (P = 0.01), early (P = 0.05) and intermediate (P = 0.01) maturity groups (Table 4). Growth rate at the seedling stage was positively correlated with emergence percent among the intermediate maturity group (P = 0.01) in the early season of this study (Table 4).

Dry weight at the seedling growth stage was positively correlated with water used at the seedling growth stage among all the maturity groups (P = 0.01). Water use efficiency at the seedling growth stage was also observed to be positively correlated with seedling water used among the extra-early (P = 0.05), early and intermediate (P = 0.01) maturity groups (Table 4). Dry weight and water used efficiency at the grain filling growth stage was positively correlated with seedling water used among the early and late maturity groups (P = 0.01) (Table 4). Positive correlation was also obtained between growth rate at seedling stage and seedling dry weight among the intermediate and late maturity groups (P = 0.01). Growth rate at the grain filling stage was also positively correlated with seedling dry weight among the early (P = 0.05) and late (P= 0.01) maturity groups. Significant positive correlations were also observed between growth rate at the grain filling stage and seedling dry weight for the early (P = 0.05) and late (P =0.01) maturity groups (Table 4). Significant positive correlations were also observed between dry weight at the grain filling stage and seedling water use efficiency (P = 0.01), Growth rate at the seedling stage and seedling water use efficiency (P = 0.01) among the intermediate maturity group and growth rate at the grain filling stage and water use efficiency at the seedling stage (P = 0.05) among the late maturity group. Dry weight and water use efficiency of the filled grains were positively correlated with water used for filled grains among the extra-early (P = 0.05), early and intermediate (P =0.01) maturity groups. On the contrary, significant negative correlation was observed between the seedling growth rate and water used to fill the grains among the intermediate maturity groups (P = 0.05). Significant positive correlations were obtained between growth rate at grain filling stage and water used at the grain filling stage (P = 0.01) among the early and intermediate maturity groups and Water used efficiency at the grain filling growth stage and growth rate at the grain filling stage among all the maturity groups (P = 0.01) (Table 4). Growth rate at the grain filling stage was observed to be positively correlated with water used efficiency among all the maturity groups (P = 0.01) (Table 4).

Table 3: Water use efficiency traits and grain yield of the maturity groups of maize for early and late cropping season of 2016 evaluated at the Teaching and Research Farm, Obafemi Awolowo University, Ile – Ife, Nigeria.

MAT.GRPS	**SDWUSD**		**SDDWT**		**SDWUE**		**GFDWT SEASONS**		**GFWUE**		**SDGR**		**GFGR**		**GYLD**	
	ES	**LS**	**ES**	**LS**	**ES**	**LS**	**ES**	**LS**	**ES**	**LS**	**ES**	**LS**	**ES**	**LS**	**ES**	**LS**
EE	81.94	190.55	3.15	20.94	0.032	0.109	14.37	87.76	0.113	0.609	0.50	3.10	1.67	14.23	1.05	2.12
E	97.45	265.58	5.30	30.11	0.047	0.114	18.24	90.29	0.137	0.603	0.82	4.24	2.29	14.01	0.78	2.91
I	96.27	125.95	5.06	11.67	0.048	0.091	27.55	72.90	0.178	0.451	0.78	1.72	3.58	10.73	0.90	1.09
L	179.85	123.85	10.71	11.62	0.058	0.093	36.56	80.76	0.239	0.521	1.58	1.66	4.56	12.84	1.69	2.61
$LSD_{0.05}$	24.40	47.93	2.00	5.87	0.012	0.007	11.33	23.78	0.067	0.177	0.30	0.74	1.39	4.75	0.79	0.74

EE: extra early; E: early; I: intermediate; L: late; ES: early season; LS: season 2; SDWUS: seedling water used; SDDWT: seedling dry weight; SDWUE: seedling water use efficiency; GFDWT: grain filling dry weight; GFWUE: grain filing water use efficiency SDGR: seedling growth rate; GFGR: grain filling growth rate; LSD: least significant difference.

Table 4: Pearson correlation among Water use efficiency traits and grain yield of the maize genotypes of different maturity groups evaluated at the Obafemi Awolowo University Teaching anf Research Farm, Ile-Ife, Nigeria during the early cropping season of 2016.

		E%	SDWUSD	SDDWT	SDWUE	GFWUSD	GFDWT	GFWUE	SDGR	GFGR
SDWUSD	EE	0.81**	-							
	E	0.61*	-							
	I	0.78**	-							
	L	0.36	-							
SDDWT	EE	0.89**	0.92**	-						
	E	0.73**	0.95**	-						
	I	0.79**	0.90**	-						
	L	0.25	0.91**	-						
SDWUE	EE	0.80*	0.66*	0.89**	-					
	E	0.82**	0.74**	0.89**	-					
	I	0.71*	0.76**	0.96**	-					
	L	0.02	0.55	0.83**	-					
GFWUSD	EE	-0.25	0.17	-0.01	-0.17	-				
	E	-0.04	0.40	0.38	0.19	-				
	I	-0.33	-0.54	-0.52	-0.37	-				
	L	-0.29	0.42	0.44	0.32	-				
GFDWT	EE	0.36	0.63*	0.42	0.19	0.64*	-			
	E	0.37	0.71**	0.74**	0.58	0.83**	-			
	I	-0.29	-0.37	-0.30	-0.12	0.86**	-			
	L	0.33	0.78**	0.82**	0.61*	0.56	-			
GFWUE	EE	0.42	0.66*	0.45	0.22	0.60*	0.99**	-		
	E	0.41	0.73**	0.76**	0.62	0.79**	0.99**	-		
	I	-0.27	-0.37	-0.27	-0.09	0.82**	0.99**	-		
	L	0.38	0.79**	0.83**	0.64	0.48	0.99**	-		
SDGR	EE	0.24	0.04	0.19	0.19	-0.13	-0.18	-0.16	-	
	E	0.04	-0.11	0.01	0.16	-0.30	-0.02	0.02	-	
	I	0.81**	0.93**	0.99**	0.92**	-0.58*	-0.36	-0.33	-	
	L	0.16	0.77**	0.73**	0.53	0.30	0.51	0.51	-	
GFGR	EE	0.38	0.57	0.41	0.24	0.37	0.82**	0.82**	-0.44	-
	E	0.08	0.60*	0.57*	0.32	0.82**	0.77**	0.73**	-0.49	-
	I	-0.04	-0.54	-0.28	-0.28	0.81**	0.90**	0.91**	-0.48	-
	L	0.28	0.74*	0.80**	0.63*	0.53	0.89**	0.90**	0.43	-
YLD	EE	0.17	-0.06	0.09	0.23	-0.47	-0.16	-0.15	0.37	-0.33
	E	0.30	0.58	0.63*	0.47	0.76**	0.88**	0.85**	-0.17	0.80**
	I	-0.25	-0.21	-0.13	0.06	0.50	0.76**	0.75**	-0.17	0.49
	L	0.31	0.53	0.58*	0.43	0.50	0.75**	0.72**	0.05	0.62*

*, ** Correlation is significant at the 0.05 and 0.01 levels 0f probability respectively,

In the late season, emergence percent and dry weight of the filled grains were positively correlated with grain yield (P = 0.01) among the extra-early maturity group while within the late maturity, water used for grain filling was positively correlated with grain yield (P = 0.01) (Table 5). Significant positive and negative correlations of seedling water used with emergence percent were observed among the early and intermediate maturity groups respectively (P=0.05). Dry weight of the seedlings were positively correlated with water used for seedling growth among all the maturity groups (P = 0.01) (Table 5). Significant positive correlations between the water used for seedling growth and efficiency of water usage at the seedling stage were also obtained among the intermediate and late maturity groups (P = 0.05). However, efficiency of water usage at the grain filling stage among the late maturity group was negatively correlated with their water usage (P = 0.05) (Table 5). Growth rate at the seedling stage had positive correlations with water used for seedling growth among the all the maturity groups (P=0.01). Positive correlations were also obtained between efficiency of water usage at the seedling stage and the dry weight of the seedlings in the extra-early (P = 0.05) and intermediate (P = 0.01) maturity groups. On the contrary, efficiency of water usage at the grain filling stage among the late maturity group was negatively correlated with their seedling dry weight (P = 0.05) (Table 5). All the maturity groups showed significant positive correlations between growth rate at the seedling stage and the dry weight of the seedling (P = 0.01). Water usage at the grain filling stage among the intermediate maturity group was positively correlated their efficiency of water usage at the seedling stage (P = 0.01). Positive correlations were also obtained between growth rate at the seedling stage and efficiency of water usage among the intermediate (P = 0.05) and late (P = 0.01) maturity groups (Table 5). Within the early maturity group, dry weight of the filled grains was positively correlated with their water used for grain filling (P = 0.01). However, among the late maturity group, efficiency of water usage at the grain filling stage and water used to fill the grains were negatively correlated (P = 0.01) (Table 5). Significant positive correlation was observed between growth rate at the grain filling stage and water used for grain filling among the maturity group (P = 0.05). In all the maturity groups, efficiency of water usage at the grain filling stage was positively correlated with dry weight of the filled grains (P = 0.01) (Table 5). Significant positive correlations were obtained between growth rate of the filled grains and their efficiency of water usage among the extra-early maturity group (P = 0.05), early. Intermediate and late (P=0.01) maturity groups (Table 5). Growth rate at the seedling stage was positively correlated with efficiency of water usage among the late maturity group (P = 0.05). In all the maturity groups, growth rate at the grain filling stage was positively correlated with efficiency of water usage at the grain filling stage (P = 0.01) (Table 5).

Table 5: Pearson correlation among Water use efficiency traits and grain yield of the maize genotypes of different maturity groups evaluated at the Obafemi Awolowo University Teaching anf Research Farm, Ile-Ife, Nigeria during the late cropping season of 2016

		E%	SDWUSD	SDDWT	SDWUE	GFWUSD	GFDWT	GFWUE	SDGR	GFGR
SDWUSD	EE	-0.24	-							
	E	0.62*	-							
	I	-0.65*	-							
	L	-0.17	-							
SDDWT	EE	-0.21	0.99**	-						
	E	0.50	0.97**	-						
	I	-0.58	0.99**	-						
	L	-0.05	0.97**	-						
SDWUE	EE	0.04	0.47	0.60*	-					
	E	-0.47	-0.28	-0.07	-					
	I	-0.11	0.67*	0.78**	-					
	L	0.27	0.58*	0.76**	-					
GFWUSD	EE	-0.24	0.50	0.50	0.15	-				
	E	0.13	0.09	0.07	0.07	-				
	I	0.09	0.25	0.39	0.71**	-				
	L	0.35	0.63	0.57	0.23	-				
GFDWT	EE	-0.33	-0.23	-0.22	0.01	0.10	-			
	E	0.15	0.12	0.02	-0.33	0.76**	-			
	I	0.57	-0.11	0.04	0.35	0.15	-			
	L	-0.11	-0.43	-0.45	-0.35	-0.38	-			
GFWUE	EE	-0.24	-0.41	-0.38	0.06	-0.49	0.77**	-		
	E	0.08	0.04	-0.09	-0.52	0.35	0.87**	-		
	I	0.48	0.02	0.05	0.29	-0.05	0.96**	-		
	L	-0.26	-0.60*	-0.61*	-0.46	-0.70**	0.81**	-		
SDGR	EE	-0.23	0.96**	0.96**	0.54	0.38	-0.17	-0.28	-	
	E	0.55	0.96**	0.97**	-0.13	0.19	0.12	-0.02	-	
	I	-0.16	0.93**	0.91**	0.58*	0.16	0.05	0.11	-	
	L	0.01	0.94**	0.98**	0.79**	0.55	-0.51	0.61*	-	
GFGR	EE	-0.48	-0.05	-0.08	-0.02	-0.38	0.63*	0.81**	0.10	-
	E	0.20	0.30	0.31	-0.38	0.61*	0.91**	0.83**	0.36	-
	I	0.30	0.07	0.11	0.37	0.07	0.83**	0.88**	0.12	-
	L	-0.24	-0.25	-0.30	-0.32	-0.33	0.94**	0.83**	-0.37	-
YLD	EE	0.73**	-0.07	-0.05	0.09	0.12	0.81**	-0.15	-0.01	-0.29
	E	0.47	-0.09	-0.22	-0.53	-0.13	0.24	0.47	-0.14	0.14
	I	0.55	-0.19	-0.14	0.15	-0.01	-0.01	0.22	-0.26	0.07
	L	0.17	0.44	0.36	-0.03	0.78**	-0.33	-0.40	0.36	-0.21

*, ** Correlation is significant at the 0.05 and 0.01 levels of probability respectively

4. DISCUSSION

The significant difference observed among the early and late cropping seasons of this study for emergence, seedling and grain filling dry weights, water use efficiency at the seedling and grain-filling growth stages, was expected since the two cropping seasons were characterized by different amount of rainfall, temperature, sunshine hour, potential evapotranspiration (PET) among other climatic attributes. This result was also corroborated by the findings of Vina *et al.,* [26] and Sivritepe et al. [27] which showed that abundant supplies of water is required for sustainable organ development. This indicated that with this climate change, favorable seasons will determine how best the performance of the maturity groups of maize will be expressed irrespective of being bred for drought tolerance.

The low coefficient of variation recorded for water used at grain filling stage showed that there were no much differences in utilization of water for different maturity groups while the high value recorded for grain filling growth rate showed much variability in the performance of the different maturity groups which indicated that rate at which different maturity groups of maize acquire dry matter on daily basis under each season varied widely. The r^2 values ranging from 0.37 to 0.89 showed the reliability of the model of the statistical analyses.

Low emergence observed during the late season compared to the early cropping season can be attributed to genetic limitations, environmental factor which can resulted in the loss of viability and vigour, during the late season. This was also observed by Ajayi and Fakorede [28] which reported that there was significant reduction in maize seed quality after three months in storage under ambient conditions. This validated the report by Bewley and Black [29] that seed quality has significant direct influence on crop productivity levels.

The significant difference between the maturity groups for the expression of the water use efficiency traits and yield difference could have been due to the difference in the duration of time to maturity of the different maturity groups. This was also observed by Oluwaranti *et al.* [23] that the time for expression of traits by genotypes varies with maturity groups. Due to the different durations of the growth stages and the amount of rainfall required by the different maize maturity groups evaluated in this study, the intermediate and late maturity groups used more water for both seedling and grain-filling growths during the early season. The efficiency of water usage and growth rates at the seedling and grain-filling growth stages was also more among the intermediate and late maturity groups than the early and extra-early maturity groups in the early season since the duration and the amount of rainfall of the early season are more than that of the late season. This result was also corroborated by the findings of Muchow [30], Oluwaranti et al. [23] and Ajani et al. [33] which reported that maturity groups highly affected the number of seedlings that emerged and the speed with which they emerged. This is in support of findings by Misra, [31] that the availability of water during the different stages of crop growth also influences crop’s survival. These same findings were supported by Vina et al. [26] which reported that if under favorable environmental conditions like temperature, soil moisture content and solar radiation, maize will produce maximum yield at different stages if supplied with adequate nutrients.

The seasonal significance for emergence and water use efficiency traits evaluated indicated that the season is taking its toll on seed viability likewise determining the rate of water uptake and utilization for seedling establishment and dry matter accumulation. Meanwhile seasons also determined anthesis-silking interval of the maize plant depending on the availability of water during the flowering period which could later contribute to yield. Interaction of the season by maturity group indicated that the season determined the level of performance of different maturity groups of maize and how efficient they are, in the establishment of the plant at the seedling and grain filling growth stages through the consumption of little amount of soil and atmospheric water in moving the assimilates from the source to the sink during these growth stages, dry matter accumulation for different maturity groups on daily basis and final yield under different seasons.

Significant maturity group difference for the water use efficiency traits indicated that the level of water absorption and utilization differed at seedling stage and at grain filling stage for the different maturity groups, likewise significance due to maturity group on yield indicated the extra-early and late maturity groups produced the highest yield in the early season while in the late season the early and late maturity groups had the highest yields. This supported the findings of Oluwaranti *et al*. [23] that different maturity groups of maize have different quality that makes them acceptable as a variety of maize.

It was also observed that the maize genotypes uses water efficiently during the early cropping season at the seedling stage but not at the grain filling stage which also affected the yield. This was because there was poor distribution of rainfall in the month of July 2016 thereby increases the atmospheric temperature for weeks which in turn drastically reduced the soil moisture content during the grain filling period. This was also reported to have been the hottest month since weather record begins and this goes in support of report by NeSmith and Ritchie [32] who observed that maize yield can be reduced by as much as 90% if drought stress occurs between a few days before tassel emergence and the beginning of grain filling. Meanwhile for grain filling water use efficiency and for dry mater accumulation on daily basis on seedling and grain filling growth rate, the late cropping season performed better.

The failure of dry matter accumulation during the early cropping season can be attributed to infestation of fall army worms which started right from five days after planting till maturity through perforation of the leaves which is supposed to be used in manufacturing food to fill the grains. The voracious consumption on leaves brings changes in the vegetative, yield and yield components while the efficient use of water during the early cropping season at seedling stage can be attributed to improved soil moisture and reduced temperature.

It was also observed that the extra early and early maturity groups of maize use water most efficiently during the early cropping season at the seedling stage indicating the extra early and early maturity group which are bred for drought escape are capable of utilizing water obtained from the soil for stand establishment and dry matter accumulation which can in turn contribute to yield. This corroborates the findings of Ajani et al. [33] that water use efficiency of rain-fed maize is important for identifying maize cultivars that are efficient in the use of limited soil water for biomass and grain yield production. During the late cropping season, the late and intermediate maturity groups of maize used water more efficiently compared to extra early and early maturity groups in the early cropping season indicating the differences in performance of the maturity groups in their ability to adapt well and utilize the little amount of water in the soil for dry matter accumulation. The performance of the maturity groups also differs in terms of flowering, yield, and yield components as also reported by [35, 23, 34]

The non-significant relationship of the water use-efficiency traits with grain yield during the early and late season among the extra-early maturity group can be explained by short growth cycle of the extra-early maturity group which resulted into inconsistent growth pattern of the maturity group. However, positive correlations were obtained between the seedling and grain-filling water use efficiency traits and grain yield during the early season among the early, intermediate and late maturity groups.

5. CONCLUSION

Maturity group of maize played a significant role in the expression and manifestation of water use efficiency traits under different environmental conditions at seedling and grain filling growth stages. Water use efficiency at the seedling stage can be used to predict water use efficiency at the grain filling stage during early and late cropping seasons of this study

COMPETING INTERESTS

Authors have declared that no competing interests exist

REFERENCES- PLEASE CHECK ALL THE REFERENCES WITH THE JOURNAL FORMAT, CAN INCLUDE MORE RECNT YEAR REFERENES

[1] FAOSTAT. Country profile. United Republic of Tanzania. Accessed on March 3, 2015. Available: http://faostat3.fao.org/home/E

[2] Amani, HKR Agricultural Development and Food Security in Sub-Saharan Africa Tanzania Country Report. *Economic and Social Research Foundation (ESRF)* Dar es Salaam, Tanzania.

[3] Zorya, S., Morgan, N. Rios L.D. Missing food: The Case of Postharvest Grain Losses in Sub-Saharan Africa. The International Bank for Reconstruction and Development / The World Bank. Report No. 60371-AFR. 2011: The World Bank, Washington, DC.

[4] BEFS, (Bioenergy and Food Security Projects). Tanzania. BEFS Country Brief. Accessed on November 6 2014). Available at: www.fao.org/bioenergy/foodsecurity/befs.

[5] Bekric V, Radosavljevic M. Savremenipristupiupotrebekukuruza. PTEP. 2008; 12:93-96.

[6] Alahdadi I, Oraki, H, Parhizkarkhajani, F. Effect of water stress on yield and yield components of sunflower hybrids. Afr J. Biotechnol. 2011; 10(34):6504-6509.

[7] Krhodarahmpour, Z. Effect of drought stress induced by polyethylene glycol (PEG) on germination indices in corn (*Zea mays* L.) hybrids. African Journal of Biotechnology 2011; 10:18222-18227.

[8] Pingali PL, Pandey S. Meeting world maize needs: Technological opportunities and priorities for public sector. Pp 1-20. *In:* 2001; Pingali, P.L. (ed.). CIMMYT 1999-2000. *World Maize Facts and Trends.* CIMMYT, Mexico.

[9] International Institute for Tropical Agriculture, (IITA). (2009). *Annual Report for 2005,* Ibadan, Nigeria: International Institute for Tropical Agriculture.

[10] Jensen JR. Remote Sensing of the Environment: An Earth Resource Perspective. 2007; 2nd Edition, Pearson Prentice Hall, Upper Saddle River.

[11] Bacon MA. Water Use Efficiency in Plant Biology. 2004; (CRC Press).

[12] Tijani FO, Oyedele DJ, Aina PO. Soil moisture storage and water-use efficiency of maize planted in succession to different fallow treatments. International Agrophysics, 2008; 22:81-87.

[13] Adamtey N, Cofie O, Ofosu-Budu KG, Ofosu-Anim J, Laryea KB, Forester D. Effect of N enriched co-compost on transpiration efficiency and water-use efficiency of maize (*Zea mays* L.) under controlled irrigation. Agricultural Water Management 2010; 97: 995-1005. doi:10.1016/j.agwat.2010.02.004

[14] Frimpong JO, Amoatey HM, Ayeh, EO, Asare DK. Productivity and soil water use by rainfed ma-ize genotypes in a coastal savannah environment. Inter-national Agrophysics 2011; **25**, 123-129.

[15] Irmark S, Haman DZ, Basting R. Determination of crop water stress index for irrigation timing and yield estimation of corn. Agronomy Journal 2000; 92, 1221- 1227. doi:10.2134/agronj2000.9261221x.

[16] Yazar A, Sezen SM, Gencel B. Drip irrigation of corn in the southeast Anatolia Project (GAP) area in Turkey. Irrigation Drainage Journal 2002; 51:293-300. doi:10.1002/ird.63

[17] Istanbulloglu A, Kocaman I, Konuku F. Water production relationship of maize under

Tekirday conditions in Turkey. *Pakistan Journal of Biological Science,* 2002; 5:287-291. doi:10.3923/pjbs.2002.287.291.

[18] Oktem A, Simsek M, Okem AG. Deficit irrigation effects on sweet corn with drip irrigation sys-tem in a semi-arid region. I. Water-yield relationship. Agricultural Water Management 2003; 61, 63-74. doi:10.1016/S0378-3774(02)00161-0.

[19] Çakir R. Effect of water stress at different development stages on vegetative and reproductive growth of corn. Field Crops Research 2004; 89:1-16.

[20] Huang R, Birch CJ, Gorge DC. Water Use Efficiency in Maize Production – the challenge and improvement strategies, Maize Association of Australia, Australia 2006.

[21] Heisey PW, Edmeades GO. Maize Production in Drought-Stressed Environments: Technical Options and Research Resource Allocation. Part 1 of CIMMYT 1997/1998 World Facts and Trends 1999

[22] Grant FR., Jackson BS, Kiniry JR, Arkin GF. Water deficit timing effects on yield components in maize. Agronomy Journal 1989; 81:61-65.

[23] Oluwaranti A, Fakorede MAB, Abebe M, Badu-Apraku B. Climatic conditions requirements of maize germplasm for flowering in the rainforest Agro-ecology of Nigeria. J. Plant Breed. Crop Sci. 2015; 7(6):170-176.

[24] Shaibu AS, Rabiu IU, Adnan AA. Variability of root and physiological traits of different maturity groups of maize (*Zea mays* L.). J. Plant Breed. Crop Sci. 2015; 7(7): 233-239.

[25] FAO. Seeds in emergencies: A technical handbook. FAO Plant Production and Protection Paper 202. FAO, Rome, Italy 2010.

[26] Vina A, Giitelson AA, Rundquist DC, Keydan G, Leavitt B, Schepers J. Monitoring maize (*Zea mays* L.) phenology with remote sensing. Agron. J. 2004; 96 :1139-1147

[27] Sivritepe HO, Sivritepe N, Senturk B. Correlation between viability and different vigour tests of maize seeds. International journal of Agriculture and Environmental Research. 2016; 02(06): 1891 – 1898

[28] Ajayi SA, Fakorede MAB. Effect of storage environments and duration of equilibration on maize seed testing and seedling evaluation. Maydica, 2001; 46:267-275.

[29] Bewley JD Black M. Seeds: Physiology, Development and Germination. 2nd Edn., Plenum Press, New York 1998.

[30] Misra, AN. Water use efficiently of pearl millet (*Pennisetum americanum* L. Leeke) genotypes under mid-season moisture stress. Acta Agronomica Hungarica 1991; 40:417-422.

[31] NeSmith DS, Ritchie JT. Effects of soil water-deficits during tassel emergence on development and yield components of maize (Zea mays L). Field Crops Res 1992; *28*, 251-256.

[33] Ajani OT, Oluwaranti, A. Awoniyi AI. Assessment of water-use efficiency of drought tolerant maize varieties in a rain forest location. Journal of Agriculture and Ecology research International 2016; 8(3): 1 -10.

[34] Akinwale RO, Awosanmi FE, Olufunmike, OO, Fadoju AO. Determinants of drought tolerance at seedling stage in early and extra – early maize hybrids. Maydica 2017; 62-

[35] Oluwaranti A, Fakorede MAB, Badu-Apraku B. Grain Yield Of Maize Varieties Of Different Maturity Groups Under Marginal Rainfall Conditions. Journal of Agricultural Sciences 2008; Vol. 53, No 3.