

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: 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

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-

25 fuel [5-7]. It is estimated that maize demand in Sub-Saharan Africa would exceed 52 million
26 tons in 2020 [8]. Despite an increased area of land which has been dedicated to cultivate
27 maize since the mid-2000s, production per hectare in the developing countries is still low
28 (1.3 t/ha) compared to the 8.6 t/ha in developed countries [9].

29 In most crops, the variation in biomass accumulation and yield production is influenced by
30 the crop's tolerance to water stress, drought, and the efficiency with which the maize crop
31 uses available soil water for growth. This led to the concept of Water Use Efficiency which
32 was broadly defined as the measure of the crop production per unit of water used,
33 irrespective of water source, expressed in units per weight of water depth per unit area, and
34 it can also be explained as the ratio of crop yield over applied water. According to Jensen
35 [10], efficiency has been defined as the ability to produce desired effect with minimum effort,
36 expenses, and waste. Several reports had shown the relationship between water use
37 efficiency and maize production [11-14]. A linear relationship was reported by [15-18,13]
38 between grain yield and water use efficiency in maize, that is, increase in water use
39 efficiency will lead to an increase in grain yield and vice versa, while a curvi-linear
40 relationship was established between water use efficiency and grain yield of maize as
41 reported by Yazar et al. [16].

42 Maize has different responses to water deficit according to its developmental stages [19, 20].
43 Drought stress is particularly damaging to grain yield if it occurs early in the growing season
44 (plant establishment), at flowering and during mid to late grain filling [21]. The most critical
45 period for water stress in maize is between 10-14 days before and after flowering, with
46 reduction of 2-3 times more when water deficit coincides with flowering compared with other
47 growing stages [22].

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

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62 **2. MATERIAL AND METHODS**

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66 **2.1 Data Collection**

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

70 The field experiments were carried out at Obafemi Awolowo University Teaching and
71 Research Farm (T&RF), Ile-Ife (latitude 7°25' N, and longitude 4°39'E), Nigeria, during the
72 early and late cropping seasons of 2016. The experiment was laid out in a randomized
73 complete block design with three (3) replicates. Plots were six rows; 5m long each, with intra
74 and inter-row spacing of 0.5m and 0.75m, respectively.

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76 **2.2 Data Collection:**

77 Emergence counts were taken on 5, 7, and 9 days after planting (DAP) to obtain emergence
78 percentage. Data on fresh weight (FWT) of the maize plants commenced nine DAP and
79 continued at five days interval to 39 DAP. Fresh weight of five ears per plot was taken 60
80 DAP at five days interval till 90 DAP for extra-early and early maturity groups and started
81 65DAP till 95 DAP for intermediate and late maturity groups. Dry weight (DWT) of the
82 collected maize plants was determined in the laboratory by oven drying at 80°C to constant
83 weight. Water stored (WSTD) was obtained from the difference between Fresh and Dry
84 weights of the samples. Water used for evapotranspiration was obtained from the product of
85 Potential Evapotranspiration (PET) of the research field and Single Crop Coefficient, (Kc),
86 where (Kc) for maize = 0.35 (FAO 1998). Weather data on the potential evapotranspiration
87 (PET) of the field was obtained from the Automatic Weather station located at the Teaching
88 and Research Farm, OAU, Ile-Ife. Cumulative Water Used was obtained from the addition of
89 the water stored with the water used for Evapotranspiration by the crop at seedling and grain
90 filling stages. Water Use Efficiency (WUE) for each maize variety was estimated from dry
91 weight of the sample and cumulative water used (Water Use Efficiency (WUE) = DWT/
92 CWU). Seedling Growth Rate (SDGR) and the Grain Filling Growth Rate (GFGR); which
93 measures the rate of dry matter production per Unit of time measures as g/day was obtained
94 by regression method with this linear regression model:

$$95 W = a + bt$$

96 Where,

97 W = dry weight per plant:

98 t = time in DAP

99 a = intercept of the regression model and

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

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102 **2.3 Statistical Analyses**

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

108 **3. RESULTS**

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110 Mean square values from combined analysis of variance due to season was highly
111 significant (P = 0.01) for emergence percentage, seedling and grain-filling water used,
112 seedling and grain-filling dry weights, water use efficiency at seedling and grain-filling growth
113 stages, growth rates at the seedling and grain-filling stages and grain yield (Table 1). Highly
114 significant (P = 0.01) maturity effects were obtained on emergence percent, seedling and
115 grain-filling water used, seedling dry weight, seedling growth rate and grain yield (Table 1).
116 Highly significant (P = 0.01) interaction of the season by maturity group was observed on
117 seedling water used, seedling dry weight, water use efficiency and growth rate at the
118 seedling stage. Significant (P = 0.05) interaction of the season by maturity group were also

119 observed on grain-filling dry weight, water use efficiency and growth rate at the grain-filling
120 growth stage and grain yield. (Table 1). The coefficients of variability (CVs) were generally
121 high for emergence, seedling water used, dry weights of the seedling and the filled grains,
122 water use efficiency at the grain filling growth stage, growth rates at the seedling and grain-
123 filling growth stages and grain yield and rather low for water use efficiency at the seedling
124 stage and water used at the grain-filling growth stage. The coefficients of determination (R^2)
125 obtained from the model for the water use efficiency traits at the seedling and grain-filling
126 growth stages were generally high which ranged from 68% to 87%, which indicated that the
127 model was highly reliable (Table 1). It was observed from the results of the evaluation of
128 water use efficiency traits and yield, that there were significantly higher means recorded for
129 most traits in the early cropping season compared to the late cropping season of this study
130 except for seedling water used, water use efficiency at the seedling growth stage, growth
131 rate at the grain-filling growth stage and grain yield in which higher values were recorded in
132 the late season (Table 2).

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

143 Efficiency of water usage at the seedling growth stage was more among the late and
144 intermediate maturing groups than the extra-early and early maturing groups in the early
145 season while in the late season, the extra-early and early maturing groups used water more
146 efficiently than the late and Intermediate maturing groups (Table 3). The intermediate and
147 late maturing groups had more dry weight of filled grains than the early and extra-early
148 maturity groups in the early season while there were no significant differences among the
149 four maturity groups for the dry weight of the filled grain in the late season of this study
150 (Table 3). Likewise, this trend of no significant difference among the four maturity groups in
151 the late season for grain-filling dry weight was also obtained for the water use efficiency at
152 the grain filling growth stage while the Late and intermediate maturity groups used water
153 more efficiently than the extra-early and early maturity groups in the early season (Table 3).
154 The seedling growth rate of the late maturity group was observed to be higher than the other
155 maturity groups in the early cropping season while in the late season, highest growth rate
156 was observed among the early maturity group followed by the extra-early maturity group with
157 the late maturity group having the lowest seedling growth rate in the late season of this study
158 (Table 3). There were no significant differences among the four maturity groups for grain-
159 filling growth rate in the late season while in the early season, the intermediate and late
160 maturity groups had the highest growth rate at the grain-filling growth stage than the early
161 and extra-early maturity groups (Table 3). There were no significant differences in the grain
162 yield among the four maturity groups during the early season of this study while the early
163 maturity group had the highest yield with the intermediate maturity group having the least in
164 the late season of this study (Table 3).

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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.

| 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; SDWUSD: 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
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2 Correlation coefficients among grain yield and water use efficiency traits at the seedling and
3 grain-filling growth stages among the extra-early, early, intermediate and late maturing
4 groups during the early and late cropping seasons of 2016 are presented in Tables 4 and 5
5 respectively. In the early season, the seedling dry weight was positively correlated with grain
6 yield among the early and late maturity groups ($P = 0.01$). Water used at the grain filling
7 growth stage was observed to be positively correlated with grain yield among the early
8 maturity group ($P = 0.01$). Positive correlations were also obtained between grain-filling dry
9 weight and grain yield among the early, intermediate and late maturity groups ($P = 0.01$)
10 (Table 4). In the early season of this study, Water used and dry weight at the seedling
11 growth stage were positively correlated with emergence percent among the extra-early ($P =$
12 0.01), early ($P = 0.05$) and intermediate ($P = 0.01$) maturity groups (Table 4). Growth rate at
13 the seedling stage was positively correlated with emergence percent among the intermediate
14 maturity group ($P = 0.01$) in the early season of this study (Table 4).

15 Dry weight at the seedling growth stage was positively correlated with water used at the
16 seedling growth stage among all the maturity groups ($P = 0.01$). Water use efficiency at the
17 seedling growth stage was also observed to be positively correlated with seedling water
18 used among the extra-early ($P = 0.05$), early and intermediate ($P = 0.01$) maturity groups
19 (Table 4). Dry weight and water used efficiency at the grain filling growth stage was
20 positively correlated with seedling water used among the early and late maturity groups ($P =$
21 0.01) (Table 4). Positive correlation was also obtained between growth rate at seedling stage
22 and seedling dry weight among the intermediate and late maturity groups ($P = 0.01$). Growth
23 rate at the grain filling stage was also positively correlated with seedling dry weight among
24 the early ($P = 0.05$) and late ($P = 0.01$) maturity groups. Significant positive correlations were
25 also observed between growth rate at the grain filling stage and seedling dry weight for the
26 early ($P = 0.05$) and late ($P = 0.01$) maturity groups (Table 4). Significant positive correlations
27 were also observed between dry weight at the grain filling stage and seedling water use
28 efficiency ($P = 0.01$), Growth rate at the seedling stage and seedling water use efficiency (P
29 $= 0.01$) among the intermediate maturity group and growth rate at the grain filling stage and
30 water use efficiency at the seedling stage ($P = 0.05$) among the late maturity group. Dry
31 weight and water use efficiency of the filled grains were positively correlated with water used
32 for filled grains among the extra-early ($P = 0.05$), early and intermediate ($P = 0.01$) maturity
33 groups. On the contrary, significant negative correlation was observed between the seedling
34 growth rate and water used to fill the grains among the intermediate maturity groups ($P =$
35 0.05). Significant positive correlations were obtained between growth rate at grain filling
36 stage and water used at the grain filling stage ($P = 0.01$) among the early and intermediate
37 maturity groups and Water used efficiency at the grain filling growth stage and growth rate at
38 the grain filling stage among all the maturity groups ($P = 0.01$) (Table 4). Growth rate at the
39 grain filling stage was observed to be positively correlated with water used efficiency among
40 all the maturity groups ($P = 0.01$) (Table 4).

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44 **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
 45 the Teaching and Research Farm, Obafemi Awolowo University, Ile – Ife, Nigeria.

| MAT.G RPS | 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 |

46 EE: extra early; E: early; I: intermediate; L: late; ES: early season; LS: season 2; SDWUS: seedling water used; SDDWT: seedling dry
 47 weight; SDWUE: seedling water use efficiency; GFDWT: grain filling dry weight; GFWUE: grain filing water use efficiency SDGR: seedling
 48 growth rate; GFGR: grain filling growth rate; LSD: least significant difference.
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54 **Table 4:** Pearson correlation among Water use efficiency traits and grain yield of the maize genotypes of different maturity groups
 55 evaluated at the Obafemi Awolowo University Teaching and Research Farm, Ile-Ife, Nigeria during the early cropping season of 2016.

| | E% | SDWUSD | SDDWT | SDWUE | GFWUSD | GFDWT | GFWUE | SDGR | GFR |
|---------------|----|--------|--------|--------|--------|--------|--------|--------|-------|
| 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 | - |
| GFR | 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 |
| | E | 0.30 | 0.58 | 0.63* | 0.47 | 0.76** | 0.88** | 0.85** | -0.17 |
| | I | -0.25 | -0.21 | -0.13 | 0.06 | 0.50 | 0.76** | 0.75** | -0.17 |
| | L | 0.31 | 0.53 | 0.58* | 0.43 | 0.50 | 0.75** | 0.72** | 0.05 |

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

1 4. DISCUSSION

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

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

17 Low emergence observed during the late season compared to the early cropping season
18 can be attributed to genetic limitations, environmental factor which can result in the loss of
19 viability and vigour, during the late season. This was also observed by Ajayi and Fakorede
20 [28] which reported that there was significant reduction in maize seed quality after three
21 months in storage under ambient conditions. This validated the report by Bewley and Black
22 [29] that seed quality has significant direct influence on crop productivity levels.

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

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

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

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

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

76 It was also observed that the extra early and early maturity groups of maize use water most
77 efficiently during the early cropping season at the seedling stage indicating the extra early
78 and early maturity group which are bred for drought escape are capable of utilizing water
79 obtained from the soil for stand establishment and dry matter accumulation which can in turn
80 contribute to yield. This corroborates the findings of Ajani *et al.* [33] that water use efficiency
81 of rain-fed maize is important for identifying maize cultivars that are efficient in the use of
82 limited soil water for biomass and grain yield production. During the late cropping season,
83 the late and intermediate maturity groups of maize used water more efficiently compared to
84 extra early and early maturity groups in the early cropping season indicating the differences
85 in performance of the maturity groups in their ability to adapt well and utilize the little amount
86 of water in the soil for dry matter accumulation. The performance of the maturity groups also
87 differs in terms of flowering, yield, and yield components as also reported by [35, 23, 34]
88

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

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96

97 **5. CONCLUSION**

98

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

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COMPETING INTERESTS

Authors have declared that no competing interests exist

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UNDER PEER REVIEW