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SEEDLING ESTABLISHMENT, BIOMASS YIELD AND WATER USE EFFICIENCIES OF FOUR MAIZE VARIETIES AS INFLUENCED BY WATER DEFICIT STRESS

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ABSTRACT. Water stress is one of the major abiotic factors affecting crop growth and development at every growth stages. Effects of water deficit on the vegetative growth stage of four maize varieties consisting of two Quality Protein Maize varieties (ILE1OB and ART98SW6OB) and two drought tolerant checks (TZPBSR and DTESTRSYN) were evaluated under the screen house conditions at the Institute of Agricultural Research and Training (I.A.R & T), Moor Plantation, Ibadan. Maize seeds were sown in 20 L plastic pots filled with 15 kg top soil, which were subjected to four watering regimes of 25, 50, 75 and 100% field capacities (FC). The experimental design was a 4 x 4 factorial fitted into CRD with four replications. Data were collected on days to germination, number of leaves per plant, leaf area, plant height, stem diameter, leaf extension rate, biomass yield and water use efficiency. The result showed that days to germination were prolonged as the moisture availability decreases, while water use efficiency increased as the moisture level reduced. Reduction in moisture availability caused significant reduction in the other evaluated parameters. At 25% FC DTESTRSYN was superior in leaf area, number of leaves per plant, days to germination and water use efficiency, TZPBSR had highest values for stem diameter and biomass yield, while ILE1OB was superior in plant height, stem diameter, leaf and stem extension rate. ILE1OB competes favourably with the drought tolerant checks and performed better than ART98SW6OB. Adequate moisture condition is fundamental for normal growth and development in maize crops.

Keywords: biomass yield; days to germination; leaf area; plant height; water use efficiency.

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INTRODUCTION

Water is an important component of life and is required for all the various biochemical and physiological processes involved in plant growth and development. Adequate moisture availability is necessary for optimum leaf development, maintenance of leaf greenness, assimilate production and partitioning as well as total dry matter yield. Water stress has adverse or deleterious effects on crops; the impact however depends on the severity of the water shortage and the developmental stage of the crop under stress (Chaves *et al*., 2002; Jaleel *et al*., 2008b). Water stress has been reported to affect the meristematic processes during the initial phase of plant growth and establishment which, consequently, impaired plant growth, as a result of reduction in cell turgidity required for mitotic cell division, elongation and enlargement (Anjum *et al.,* 2003a; Bhatt and Srinivasa Rao, 2005; Jaleel *et al.,* 2008). Reactive oxygen species (ROS) are produced by plants under severe water deficit condition, which in turn damage plant cells and, consequently, lead to plant death. In soybean significant reduction in stem length, biomass yield and leaf development, as a result of water stress was reported by Specht *et al*. (2001) and Zhang *et al*. (2004), while about 25% reduction in plant height was observed in citrus seedlings under water deficit stress (Wu *et al*., 2008).

Plant genotypes differed in their response to water stress depending on the extent of the stress, duration of the stress and the stage of growth of the plant (Chaves *et al*., 2002; Blum, 2005; Jaleel *et al*., 2008). Naturally, plants possess various kinds of adaptive mechanisms to cope with water deficit stress, such includes production of antioxidant to annul the lethal effect of reactive oxygen species (ROS) (Hare *et al*., 1999), dehydration avoidance, osmotic adjustment, tolerance and reduction in water use (Blum, 2005). Plants also maintain cellular water content by closing their stomata to prevent desiccation, development of smaller and fewer numbers of leaves and premature death of the older leaves to sustain the younger and newly emerging leaves. The mechanisms of cellular water content conservation, employed by many plants during extreme water shortages are, usually detrimental to yield. In maize, the reproductive stage is usually considered as the most critical stage or sensitive stage to water deficit stress. However, the impact of water deficit stress on the vegetative growth stage in maize plants development cannot be underestimated. This is because, the vegetative growth stage is actually the period of the development of various yield components that are essential for efficient photosynthetic activities, assimilate build that would later be partitioned to the sinks.

The objective of this study was to determine the effect of water deficit stress on the vegetative stage growth and development of two recently released Quality Protein Maize varieties maize varieties (ILE1OB and ART98SW6OB) and two drought tolerant maize varieties (DTESTRSYN and TZPBSR).

MATERIALS AND METHOD

The experiment was conducted in the screen house of the Institute of Agricultural Research and Training (I.A.R & T), Moor Plantation, Ibadan. I.A.R & T is located on Lat. 7°22.5‘N and Long. 3°50.5‘E within tropical rain forest derived savannah transitional zone. Institute of Agricultural Research and Training (I.A.R & T) has a bimodal rainfall pattern, with a long rainy season, usually between March and July and a short rainy season, usually extending from September to early November, after a short dry spell in August and a longer dry period from December to February. The moisture content of the soil was determined by gravimetric/oven-dry method, so as determine the quantity of water needed to give the required water equivalent of the intended field capacities (FC). Similarly, the pre-planting soil analysis for the determination of the textural classification and the physico-chemical properties of the soil was carried out. The soil was a loamy sandy soil with 82% sand, pH of 6.63 and chemical properties of 5.3 g/kg Organic carbon, 0.1 g/kg Nitrogen, 7.0 mg/kg of P, 1.1 cmol/kg of Ca, 1.8 cmol/kg of Mg, 0.2 cmol/kg of K, 0.4 cmol of Na, 0.1 cmol/kg total acidity and 1.36 g/cm^3 bulk density.

Planting operations

Two seeds each of open populated four maize varieties (two recently released quality protein maize varieties ART98SW6OB and ILE1OB, and two drought tolerant check TZPBSR and DTESTRSYN) were sown in each of the 64 plastic pots of 20 L capacity, each filled with 15 kg of top soil, which had already been air-dried and sieved using 2 mm sieves. Four maize varieties and four simulated water regimes of 25, 50, 75 and 100% field capacities were evaluated in a 4 x 4 factorial arranged in a CRD in four replications. The water regimes constituted the main plot, while the varieties were the sub plots. The amount of water loss during each measuring cycle was replaced so as to bring the pots back to their initial weight. A graduated measuring cylinder was also placed at the centre of the screen house to determine the quantity of daily water evaporation. Measurements on the growth and yield were taken weekly in the morning and the amount of watering requirement for each soil moisture treatment was added as at when required. Plants were watered regularly to the designated field capacity and the soil moisture potential was guided by quick and drawn Tensiometer (Eijkelkamp.co). The plants in each pot were thinned to one vigorous seedling at 7 days after planting. Basal fertilizer application of 7.02 g of N.P.K 20:10:10 was applied to each of the pots, while weeding was done manually throughout the period of the experiment.

Data collection

Data were taken on a weekly basis on days to germination (obtained by visual estimation of emerged plumule from 4 days after sowing). Number of leaves per plant was also determined by visual counting, while leaf area was measured in centimeter-square by measuring the length and breadth of a fully expanded tagged leaf. The product was then multiplied by 0.75, which is the calibration factor for maize leaf (Francis *et al*., 1969). Plant height was determined using meter rule and measured in centimeter from the base of the plant to the base of the last emerged leaf), stem diameter was measured in centimeter using the Vernier caliper, stem and leaf extension rate was determined on weekly basis by comparing the differences between present seedling height/leaf length and the last measured seedling height /leaf length and dividing it by the measurement intervals in days (Olaoye *et al*., 2009). Crop Growth Rate per plant (CGR) was calculated as (DMW) / DT, where DMW is the average dry matter weight of one plant in grams and DT is the total growth period (time in days) (Fageria *et al.,* 2006). Biomass yield (the shoot, leaves and root) were separated and dried to constant weight in an oven at $70^{o}C$ and the accumulated biomass was weighed on electronic digital weighing scale. Water use efficiency (WUE) was also estimated using the formula: WUE = [Dry Matter production/Amount of H_2O used]. The data obtained from the measurement of the various parameters were analyzed using Statistical Analysis System (SAS Int., 2009). Significant means were separated using the Fisher's protected LSD test.

RESULTS

Days to germination

Days taken by seed from different treatments to germinate varied significantly based on different watering regimes and variety. Earliest days of germination was observed at 100% field capacity (FC), where the seeds sprouted within 4.81 days of germination, while it took extra 0.38, 0.87 and 1.38 day (s) for seeds to germinate under 75% FC, 50% FC and 25% FC (*Table 1*). DTESTRSYN germinated earliest within 4.81 days, while germinations in the other three varieties were delayed till 6.06, 5.75 and 5.68 days in TZPBSR, ILE1OB and ART98SW6OB. Seedling emergence within the various watering regimes and varieties also differed significantly at $p<0.05$, most especially under 25%, 75% and 100% FC, whereas at 50% FC no significant difference was observed (*Table 2*). The result obtained revealed that rate of seed germination reduced as the moisture availability decreased. DTESTRSYN emerged earliest across the various W x V interaction levels and was significantly different from the other three varieties: TZPBSR, ILE1OB and ART98SW6OB.

Number of leaves per plant

Number of leaves per plant was significantly influenced by varying watering regimes (W) ($p<0.001$) and varieties (V) ($p<0.01$), but W x V interaction was not significant. Number of leaves increased as moisture availability increased in this study (*Table 1*). Highest number of leaves 13.43 was obtained under well-watered conditions of 100% FC, followed by 75% FC, which was 12.87, while 11.37 and 9.88 leaves per plant were obtained under reduced moisture conditions of 50 and 25% FC, respectively. The overall performance of the varieties, as regards to the number of leaves produced per plant in this study, showed that DTESTRSYN and ART98SW6OB had 12.25 and 12.43

leaves, which were similar but significantly higher than ILE1OB, which had 11.06 leaves. Numbers of leaves varied significantly within 25 ($p<0.01$) and 100% FC ($p<0.001$) water regime–variety interaction levels, while no significant differences were noticed at 50 and 75% FC interaction levels (*Table 2*). ILE1OB had 15.00 leaves per plant and was superior to 13.50 and 13.25 leaves obtained in TZPBSR and DTESTRSYN, which were similar in number of leaves, while ART98SW6OB had the least number of 12.00 leaves, when W x V interaction was at 100% FC. DTESTRSYN produced highest number of leaves per plant (11.00) at 25% FC and was significantly higher than 10.25 and 9.75 leaves produced by ILE1OB and TZPBSR, while ART98SW6OB was least with 8.50 leaves.

Plant height and stem extension rate

Plant height was highest under full watering condition of 100% FC (66.81 cm), followed by 75% FC and 50% FC, while 25% FC gave the lowest plant height. The varieties also differed in their response to the varied moisture conditions, DTESTRSYN and ILE1OB gave the highest plant heights of 50.44 and 50.00 cm, respectively, which were significantly higher than TZPBSR, which had the lowest height of 42.69 cm, while ART98SW6OB was 44.63 cm (*Table 1*). Water regime-variety interaction on plant heights was not significant at 100, 75, and 50% FC's, except at 25% FC (*Table 2*), where ILE1OB had highest height of 31.25 cm and significantly higher than TZPBSR and DTESTRSYN, which had similar heights of 27.00 cm and 30.75 cm ART98SW6OB had lowest plant height of 21.75 cm. Stem extension rate was significantly influenced by varying simulated water regime (W) at $p<0.001$, while variety (V) and variety-water interactions (W x V) were not significant. High moisture condition favored rate of stem extension and decreased as the moisture availability reduced (100%>75%>50%>25% FC) (*Table 1*). The fastest rate of stem extension rate (1.57) was observed when watering was at 100% FC and this was significantly higher than 1.23 and 0.91 extension rate obtained when moisture level were at 75 and 50% FC respectively, while rate of stem extension was lowest at 25% FC (0.59). Stem extension rate increased as the water regime-variety interaction levels increased in this trial (*Table 2*). No significant difference was observed in the varieties response within the various water regime levels except when watering was at 25% ($p<0.05$) watering field capacity. Under this moisture level TZPBSR and ILE1OB had highest stem extension rate of 0.67 and 0.61 and were superior to 0.59 observed in DTESTRSYN, while least extension rate of 0.49 was observed in ART98SW6OB. The stem extension rate increased beyond fifth week of plant emergence (*Fig. 1*).

Table 1 - Main effects of different watering regime and variety on the growth and yield components of four maize varieties evaluated in the screen house in Ibadan

Treatments	Days to germination	Number of leaves/plant	Plant height (cm)	Stem diameter (cm)	Leaf area (cm^2)	Leaf extension rate	Stem extension rate	Crop growth rate (g/day)	Biomass yield (g/plant)	Water use efficiency (g/l)
Water regime										
25	6.19a	9.88c	27.68d	3.76c	144.8d	1.32c	0.59d	0.10d	3.89d	7.15a
50	5.68ab	11.37b	39.62c	4.64b	213.1c	1.68b	0.91c	0.25c	9.64c	5.46b
75	5.19bc	12.87a	53.62b	5.43a	292.5b	2.08a	1.23b	0.39b	14.86b	3.31c
100	4.81c	13.43a	66.81a	5.38a	325.4a	2.23a	1.57a	0.49a	19.88a	3.06c
Variety										
TZPBSR	6.06a	11.81ab	42.69b	5.13a	247.7ab	1.76b	0.99a	0.30ab	11.70a	4.46ab
ILE1OB	5.75a	11.06b	50.00a	5.08a	269.7a	2.15a	1.14a	0.31ab	12.90a	4.76a
ART98SW6OB	5.68a	12.25a	44.63ab	4.45b	220.9b	1.71b	1.07a	0.27b	10.67a	3.49b
DTESTRSYN	4.37b	12.43a	50.44a	4.58b	237.4ab	1.65b	1.12a	0.35a	13.02a	4.27ab
F test										
Water (W)	***	***	***	***	***	***	***	***	***	***
Variety (V)	***	**	**	**	*	**	ns	*	ns	*
W x V	**	*	*	*	*	*	*	*	*	*
$LSD\alpha_{0.05}$	0.58	0.58	6.65	0.34	32.55	0.29	0.16	0.07	2.65	0.86

* ** *** significant at p=0.05, 0.01, 0.001; ns=not significant;† Means not followed by the same letter within a column are significantly different according to Fisher's protected LSD test at p=0.05.

Table 2 - Effect of watering regime (W) and variety (V) interaction (W x V) on the growth and yield components of four maize varieties in evaluated in the screen house under four watering regimes in Ibadan

Treatments	Days to germination	Number of leaves/plant	Plant height (cm)	Stem diameter (cm)	Leaf area (cm^2)	Leaf extension rate	Stem extension rate	Crop growth rate (g/day)	Biomass yield (g/plant)	Water use efficiency (g/l)
25% FC x TZPBSR	7.25a	9.75b	27.00ab	4.27a	144.7ab	0.94b	0.67a	0.11a	4.43a	8.81a
25% FC x ILE1OB	6.50a	10.25ab	31.25a	4.25a	165.7ab	1.77a	0.62a	0.10a	4.26ab	8.28a
25% FC x ART98SW6OB	6.70a	8.50c	21.75b	3.30b	97.93b	1.09ab	0.49b	0.06a	2.57b	5.13a
25% FC x DTESTRSYN	5.00b	11.00a	30.75ab	3.25b	170.7a	1.49ab	0.59ab	0.11a	4.34ab	6.17a
F- test	*	**	*	**	*	*	*	ns	*	ns
50% FC x TZPBSR	6.25a	11.00a	35.75a	4.65a	197.2a	1.56a	0.85a	0.19b	7.70b	2.79b
50% FC x ILE1OB	6.00a	11.00a	38.50a	4.87a	241.8a	1.83a	0.89a	0.25b	9.80ab	3.65ab
50% FC x ART98SW6OB	5.50a	11.50a	39.25a	3.95b	184.4a	1.56a	0.92a	0.22b	8.19b	2.97ab
50% FC x DTESTRSYN	5.00a	12.00a	45.00a	5.00a	223.9a	1.75a	0.97a	0.36a	12.85a	4.34a
F- test	ns	ns	ns	*	ns	ns	ns	*	*	*
75% FC x TZPBSR	5.50a	13.00a	49.25a	5.53a	312.6a	2.29ab	1.08a	0.34a	13.07a	2.90a
75% FC x ILE1OB	5.25a	12.75a	55.75a	5.58a	335.2a	2.61a	1.29a	0.39a	16.58a	3.68a
75% FC x ART98SW6OB	6.00a	12.25a	50.75a	5.45a	275.0a	1.82bc	1.24a	0.36a	13.69a	3.04a
75% FC x DTESTRSYN	4.00b	13.50a	58.75a	5.18a	247.1a	1.39c	1.32a	0.47a	16.13a	3.62a
F- test	**	ns	ns	ns	ns	*	ns	ns	ns	ns
100% FC x TZPBSR	5.25a	13.50b	58.75a	6.05a	336.2a	2.25a	1.35a	0.56a	21.62a	3.33a
100% FC x ILE1OB	5.00a	15.00a	74.50a	5.63ab	321.6a	2.38a	1.76a	0.51a	20.95a	3.22a
100% FC x ART98SW6OB	5.00a	12.00c	66.75a	5.10ab	336.1a	2.37a	1.64a	0.42a	18.21a	2.79a
100% FC x DTESTRSYN	4.00b	13.25b	67.25a	4.78b	307.8a	1.95a	1.54a	0.45a	18.77a	2.88a
F- test	***	***	ns	*	ns	ns	ns	Ns	ns	ns

* ** *** significant at p=0.05, 0.01, 0.001; ns=not significant; † Means not followed by the same letter within a column are significantly different according to Fisher's protected LSD test at p=0.05.

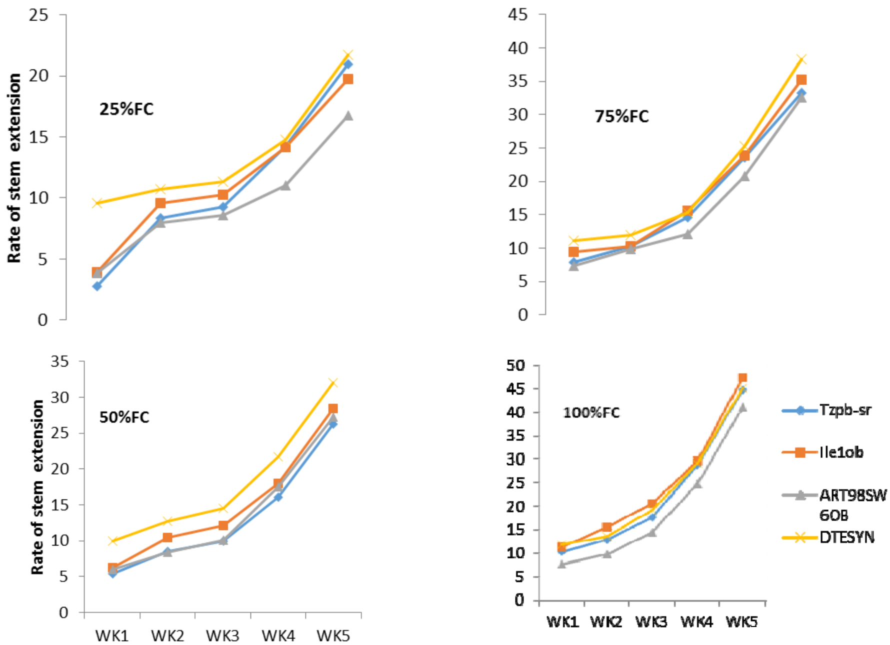

Figure 1 - Weekly stem extension rates of four maize varieties under 25, 50, 75 and 100 % watering field capacities

Leaf area and leaf extension rate

Leaf area was significantly influenced by varying watering regime and varieties (V), while water regime and variety interaction was significant at $p<0.05$. Leaf area formation was optimum under 100% FC, but reduced as the moisture level decreased (*Table 1*).

Broadest leaf area of 325.4 cm^2 was obtained when watering was at 100% FC. This value was significantly higher than 292.5 and 213.1 cm^2 obtained when moisture level were at 75 and 50% FC. Least leaf area size of 144.8 cm^2 was obtained at 25% FC. The varieties however differed significantly in the sizes of leaf area formed. ILE1OB had highest leaf area size of 269.7 cm^2 and was significantly higher than 247.7 and 237.4 cm^2, obtained in TZPBSR and ART98SW6OB, respectively, while the least leaf area of 220.9 cm^2 was obtained at 25% FC. Leaf area was not significant across the different water regime-variety interaction levels, except at 25% field capacity $p<0.05$ (*Table 2*). At 25% water application level, highest leaf area of 170. 79 cm^2 was observed in DTESTRSYN and this was significantly higher than 144.7 cm^2 and 165.7 cm^2, observed in TZPBSR and ILE1OB, which were not significantly different, while ART98SW6OB had lowest leaf area size of 97.93 cm^2.

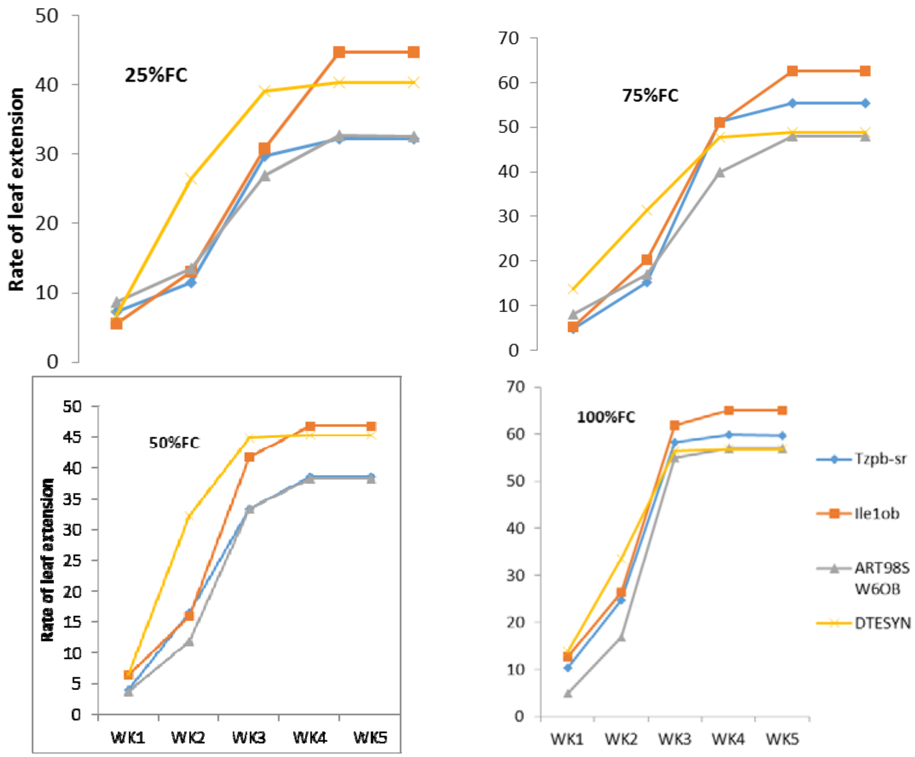

Figure 2 - Weekly (WK) leaf extension rates of four maize varieties under 25, 50, 75 and 100% watering field capacities

The rate of leaf extension was also optimum at 100% FC, and reduced as the watering level reduced (*Table 2*). Rapid leaf extension rates of 2.23 and 2.08 were observed at 100 and 75% and declined to 1.68 and 1.32, when watering were at 50 and 25% FC. The varieties had different leaf extension rate and the most rapid extension rate of 2.15 was observed in ILE1OB and which was significantly higher than the other three varieties (*Table 1*). Leaf extension rate also differed across the various water regime-variety interaction levels and increases with increased moisture availability (*Table 2*). No significant differences were observed in the rate of leaf extension under 100 and 50% water regime and variety interaction, but significant differences at $p<0.05$ when watering were at 25 and 75% FC respectively. Fastest rate of leaf area extension of 2.60 was observed in ILE1OB, under high moisture condition of 75% FC; this value was superior to 2.29 and 1.81 recorded for TZPBSR and ART98SW6OB, while lowest leaf extension rate of 1.39 was observed in DTESTRSYN. At 25% FC, ILE1OB had the highest leaf extension rate of 1.77 and was superior to ART98SW6OB (1.09) and DTESTRSYN (1.49), while TZPBSR (0.94) had the lowest leaf extension rate. The rate of leaf extension under the four watering regimes increased continuously and steadily until the fifth week, while no further extension was observed after the fifth week of emergence (*Fig. 2*).

Stem diameter

Stem diameter was significantly affected by the different watering regime and varieties at $p<0.01$. Stem diameter reduced as moisture availability decreased. Highest but similar stem diameter sizes were obtained when watering were at 75 % (755.43 cm) and 100% FC (5.38 cm) and were significantly higher than 4.74 cm obtained under 50% FC and 25% FC (3.76 cm) respectively (*Table 1*). The varieties also varied significantly in their stem diameter sizes in this study. TZPBSR and ILE1OB had highest stem diameter sizes of 5.13 and 5.08 cm, which were significantly higher than 4.58 and 4.48 observed in ART98SW6OB (*Table 1*). Stem diameter differed significantly across the various water regime and variety interaction levels and increased with increase in moisture availability except at 75% FC, where no significant difference was observed (*Table 2*). At 25% FC TZPBSR (4.27) and ILE1OB (4.25 cm) had highest stem diameter sizes and were significantly higher than ART98SW6OB (3.30) and DTESTRSYN (3.25 cm). At 50% FC, TZPBSR (4.65), ILE1OB (4.87) and DTESTRSYN (5.00 cm) had highest diameter and were significantly higher than ART98SW6OB (3.95 cm). Highest stem diameter size was observed in TZPBSR (6.05 cm) at 100% FC, TZPBSR was however significantly higher than ILE1OB (5.63) and ART98SW6OB (5.10 cm) and DTESTRSYN (4.78 cm).

Crop growth rate (CGR)

Crop growth rate was significantly different under different watering regimes and variety (V), variety and water regime (W) interactions were also significant (*Table 1*). Crop growth rate reduced drastically as the moisture availability level declined. Crop growth was highest when moisture level was at 100% FC (0.49 g/day); this was significantly higher than CGR, obtained when irrigation levels were 75 (0.39) and 50% FC (0.25 g/day), respectively, while the lowest CGR of 0.10 g/day was obtained at 25% FC. DTESTRSYN had the highest CGR of 0.35 g/day and was significantly higher than 0.30 and 0.31 g/day observed in TZPBSR and ILE1OB and ART98SW6OB, which had the least CGR of 0.27 g/day. Water (W) x variety (V) interactions (W x V) for crop growth rate were not significantly at 100%, 75% and 25% FC’s (*Table 2*). However, CGR was significant at $p<0.05$, when water regime-variety interaction was at 50% FC. DTESTRSYN had the highest CGR of 0.36 and was superior to 0.22, 0.25 and 0.19 g/day of

ART98SW6OB, ILE1OB and TZPBSR.

Biomass yield (BMY)

The total biomass yield was significantly influenced by water regime (W), variety (V), while W x V interaction was significant. Biomass yield obtained in this study decreased as soil moisture level decreased. Highest biomass yield of 19.88 g was obtained at 100% FC, and was significantly higher than 14.86, 9.64 and 3.89 g biomass yield obtained when moisture levels were at 75, 50 and 25% FC (*Table 1*). BMY differed significantly at 25% and 50% water regime-variety interaction levels. At 25% field capacity, TZPBSR (4.43 g) had the highest BMY and was significantly higher than ILE1OB (4.26), DTESTRSYN (4.34 g) and ART98SW6OB(2.57g).DTESTRSYN (12.85 g) gave the highest BMY at 50% FC and was significantly higher than BMY observed in ILE1OB (9.80 g), TZPBSR (7.70 g) and ART98SW6OB (8.19 g) (*Table 2*).

Water use efficiency (WUE)

Highest WUE of 7.15 g/l was obtained at 25% FC, followed by 50% FC (5.46 g/l), respectively (*Table 1*), while the lowest WUE were obtained at 75% (3.31) and 100% FC (3.06 g/l). The varieties differed significantly in water use efficiency in this study. Highest water use efficiency of 4.76 g/l was observed in ILE1OB and was significantly higher than WUE, obtained by TZPBSR (4.46) and DTESTRSYN (4.27 g/l), while ART98SW6OB had the least WUE value of 3.49 g/l (*Table 1*). Within the various water regime-variety interaction levels WUE did not differ significantly, except at 50% moisture level, where the level of significance was at $p<0.05$. At this moisture level, DTESTRSYN had the highest WUE value of 4.34 g/l and was significantly higher than ILE1OB (3.65 g/l), ART98SW6OB (2.97 g/l) and TZPBSR (2.79 g/l) (*Table 2*).

DISCUSSION

Seed germination and seedling establishment are fundamental to the survival and growth of plant (Hadas, 1977). These processes are regulated by the duration and amount of moisture in the growth environment (Schütz and Milberg, 1997). Moisture stress reduced the percentage and rate of germination and seedling growth as observed in this study, in such that as the moisture availability reduces the means germination time (MGT) increases. This finding corroborates the work of Harris *et al*. (2002), Delachiave and de Pinho (2003) and Willenborg *et al*. (2004), which ascribed impaired seed germination and poor seedling establishment as consequences of drought. The different varieties in this study varied in their responses to the varying watering regimes most, especially under water limited condition. Drought tolerant variety DTESTRSYN germinated earliest than the other non tolerant varieties, especially when watering regime was

25 and 50% FC. Kramer (1974) had earlier attributed growth reduction in germinating seed to decline in cellular expansion to plant under water stress. Adequate watering favours germination of seeds and this finding agreed with the previous report on the impact of moisture availability and germination in seeds. Wenkert *et al.* (1978) linked decline cellular elongation and reduced carbohydrate wall synthesis to water stress in germinating seed. Growth and yield components, such as stem length and extension rate, stem diameter, evaluated in this study, reduced significantly as moisture availability reduces. Bhatt and Srinivasa Rao (2005) and Anjum *et al*. (2011) had earlier attributed, such reduction in plant height of plant under water stress to decline in the cell enlargement processes. Wu *et al.* (2008) observed an estimate of about 25% reduction in plant height of citrus seedling under water stress. Similarly, Specht *et al*. (2001) observed a significant stem length reduction in soybean subjected to water stress. Number of leaves per plant, leaf area and leaf growth rates, leaf total biomass were severely reduced under water deficit stress at 25 and 50% FC in this study, such reduction had been earlier reported in soybean by Zhang *et al*. (2004) and in wheat (Sacks *et al*., 1997). Rate of leaf extension was very rapid between the 1st and 3rd week after emergence in maize evaluated under varying watering regimes in this study. Shortage of water availability at this stage could lead to permanent negative effect on the total leaf size and length. Inhibitory effects of water deficit stress on leaf expansion, leaf development and reduced light interception results in reduced dry matter production in plant (Nam *et al*., 1998). Reduction in dry biomass production, which is a common adverse effect of water stress, was also observed in this study, which is related to the findings of Zhao *et al*. (2008) and Farooq *et al*. (2009a).

Water use efficiency (WUE) increased as the moisture availability reduced in this study, this finding agreed with the report of Mueller *et al*. (2005), which observed that WUE is most efficient when optimum advantage is gained from least amount of water available to the plant. On a general note, crop growth rate (CGR) described by Fageria *et al*. (2006) as an average dry matter of one plant in grams over the total growth period in days was optimum under well watered condition and was minimal under water stress condition. Crop growth resulting from the aggregates of cellular activities within the plant organelles is influenced by various biotic and abiotic factors. Cell growth is one of the most drought sensitive physiological processes due to reduction in turgor pressure as growth is effected when daughter cells are produced by meristematic cell divisions and, subsequent, massive expansion of the young cells. Flow of water from the xylem to the surrounding cells becomes interrupted there by impairing mitosis; cell elongation and expansion resulting in reduced growth and yield traits (Nonami, 1998 and Hussain *et al*., 2008).

CONCLUSION

Water deficit stress reduced the various activities involved in growth and developmental processes in maize varieties evaluated in this study. Reduction in the final number of leaves formed per plant, leaf area, plant heights are all indicative of reduced photosynthetic activities and consequent low yield. Morpho-physiological variations exhibited by these maize varieties at 25%FC could be used as basis of drought tolerant maize selection, and therefore could be improved by breeding and biotechnological tools to further improve their yield potentials for drought environments. Maize varieties ILE 1OB competes favourably with the drought tolerant checks (DTESTRSYN and TZPBSR) and was better adapted to water deficit stress than ART98SW6OB,

The response of these maize varieties to water deficit stress should be further subjected to field evaluation.

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