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Effects of soil nutrient amendments on growth and grain yield performances of quality protein maize grown under water deficit stress in Ibadan, Nigeria

Folake ANJORIN [1, 2], Adeyinka ADEBAYO [1], Taiwo OMODELE [1], and Adewale ADETAYO [1], James ADEDIRAN

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Abstract: Drought and poor soil fertility are major limitations to crop production, globally. To investigate the impacts of water deficit stress (WS) and soil nutrient amendment (SA) on growth and yield performances of maize. A two years factorial field study was carried out, using a quality protein maize (QPM) (ILE-1-OB) and a non QPM–drought tolerant check (TZPBSR-W) varieties in Ibadan. Treatments include; six fertilizer application rates; 50 and 100 (kg N ha^{-1}) of NPK-20-10-10, 10.7 kg N ha^{-1}of Tithonia Poultry Compost (TPC), 50 N + 10.7TPC and 100 N + 10.7TPC (kg N ha^{-1}), three WS; the control (FW), WS at vegetative stage (STR1), and WS at reproductive stage (STR2). Leaf area (LA) and grain yield (GY) were measured using standard procedures. From the results, across WS, LA ranged from STR1 (458.90 ± 12.4) to FW (598.81 ± 13.1 cm^2), GY varied from STR2 (2.94 ± 0.2 t ha^{-1}) to FW (6.59 ± 0.2 t ha^{-1}), across fertilizers, LA varied from 0 N (397.65 cm^2) to 100N + 10.7TPC (622.71 cm^2) and 50 N + 10.7TPC (611.03 cm^2), respectively. The GY varied from 0 N (2.37 t ha^{-1}) to 100 N + 10.7TPC (5.82 t ha^{-1}) and 50N + 10.7TPC (5.26 t ha^{-1}). Drought stress reduced growth and GY performances of QPM, while SA with 50 kg N ha^{-1} of inorganic fertilizer and 10.7 kg N ha^{-1} of TPC enhanced growth and grain yield of maize under WS.

Key words: fertilizer application rates; grain yield; growth and yield performances;quality protein maize; soil nutrient amendments; water deficit stress

Učinki gnojenja na rast in pridelek zrnja na proteinih obogatene koruze v razmerah sušnega stresa, Ibadan, Nigeria

Izvleček: Suša in slaba rodovitnost tal sta v globalnem obsegu glavna dejavnika, ki omejujeta produktivnost gojenih rastlin. Za preučevanje vpliva vodnega deficita (WS) in dodajanja hranil v tla (SA) na rast in pridelek koruze je bil izveden dvoletni faktorski poljski poskus na sorti ILE-1-OB, bogati na proteinih (QPM) in na sušo odporni sorti TZPBSR-W kot kontroli, ki ni obogatena s proteini (non QPM), v Ibidanu, Nigerija. Obravnavanja so obsegala: šest načinov gnojenja (50 in 100 (kg N ha^{-1}) z NPK-20-10-10, 10,7 kg N ha^{-1} komposta iz vrste *Tithonia* pomešanega s kokošjim gnojem (TPC), 50 N + 10,7 TPC in 100 N + 10,7 TPC (kg N ha^{-1}), tri stopnje vodnega deficita (WS) v vegetativni (STR1) in reproduktivni fazi (STR2) in kontrolo s polnim namakanjem. Listna površina (LA) in pridelek zrnja (GY) sta bila izmerjena s standardnimi metodami. Listna površina je v vegetativni fazi ob pomanjkanju vode znašala 458,90 ± 12,4 cm^2, ob polnem zalivanju pa 598,81 ± 13,1 cm^2. Pridelek zrnja je ob vodnem deficitu v reproduktivni fazi znašal 2,94 ± 0,2 t ha^{-1}, pri polnem zalivanju pa 6,59 ± 0,2 t ha^{-1}. Listna površina je bila glede na načine gnojenja sledeča: 0 N (397,65 cm^2), 100 N + 10,7 TPC (622,71 cm^2) in 50 N + 10,7 TPC (611,03 cm^2). Pridelek zrnja je glede na načine gnojenja dosegel naslednje vrednosti: 0 N (2,37 t ha^{-1}), 100 N + 10,7 TPC (5,82 t ha^{-1}) in 50 N + 10,7 TPC (5,26 t ha^{-1}). Sušni stres je zmanjšal rast in pridelek sorte QPM, gnojenje s 50 kg N ha^{-1} kot anorganskim gnojilom dopolnjeno z 10,7 kg N ha^{-1} v organski obliki je pospešilo rast in pridelek zrnja koruze v razmerah vodnega deficita.

Ključne besede: na proteinih obogatena koruza**;** odmerki in vrste gnojil; rast; pridelek zrnja; sušni stress

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[1] Institute of Agricultural Institute Research and Training, Obafemi Awolowo University, Ibadan, Nigeria
[2] Corresponding author, e-mail: folakeawoeyo@yahoo.com

1 INTRODUCTION

Maize is an important cereal crop with wide range of utilization in several countries of the world. Apart from been a major staple crop, maize is an important ingredient in livestock feed formulation for the rising poultry business in the sub Saharan Africa. Maize has remained a unique crop with great potentials to survive across different agro-ecology and vegetations, globally. However, the detrimental impacts of drought and poor soil fertility on profitable maize production in the tropics cannot be overemphasized (Goldblatt, 2010; Ammani et al., 2012). Unpredictable weather conditions, erratic rainfall patterns, and incidences of occasional pockets of drought even at the peak of rains are characteristics attributes of Nigeria's climate, lately. The consequences of climate change are gradually having its turn on the nation's vegetation and cropping system.

An estimated value of about 15 % reductions in global maize production has been attributed to drought alone (Edmeades, 2013). Inadequate water availability affects virtually all physiological and metabolic processes in maize development. Processes such as germination, seedling growth, leaf formation, stem elongation, and overall crop development (Anjorin et al., 2017; Anjorin et al., 2018). The severity of damage resulting from drought stress depends on the duration of drought and the phenological stage of plant development as at time of stress (Chaves et al., 2002; Jongdee et al., 2002). The reproductive developmental stage has been shown to be the most critical stage for maize sensitivity to drought. Monneveeux et al. (2006) in a similar view, reported that grain yield in maize could be drastically reduced by drought prolonged beyond 12 days during grain filling and flowering stages.

Apart from drought, uncontrolled soil nutrient mining due to continuous cropping without supplementary replacement has been a common and regular practice in most countries of sub-Saharan Africa (Ngetich et al., 2012). An estimated average annual nutrient depletion ranged from 20 kg to 50 kg NPK ha^{-1}yr^{-1} in majority of developing countries to more than 100 kg NPK ha^{-1}yr^{-1} in the least developed countries of Africa (Tan et al., 2005).

Crops appear more devastated especially when both drought and nutrient stresses occur simultaneously. However, the use of drought tolerant crop genotypes and fertilizers has the potentials to enhance crop growth and yield in the face of prevailing climatic challenges. Over time, several integrated soil fertility management strategies (ISFM) that could enhance soil fertility potentials and productivity in Africa had been advocated (Scoones & Toulmin, 1998). These include the use of fertilizers, organic inputs and improved germplasm in addition to the technicalities of adapting these practices to local environments (Vanlauwe et al., 2010; Sanginga & Woomer, 2009).

Therefore, there is a need for a balance in moisture and nutrient availability in the crop environment with regards to stages of plant development for optimum crop yield. As at present much work has not been carried out in this part of the world on soil fertility management strategies with regards to occurrences of drought during various phenological growth stages in maize. Hence, this study aimed at assessing the impact of inorganic and organic fertilizers (using *Tithonia* poultry compost) soil amendment interventions at ameliorating the impact of water deficit stress (drought) on maize phenology.

2 MATERIALS AND METHODS

2.1 EXPERIMENTAL SITE, LOCATION AND DESIGN

The study was conducted on the research field (Longitude 3°50'56.1"E and latitude 7°22' 20" N) during the dry seasons between Decembers – March in 2014/ 2015 and 2015/2016 at the Institute of Agricultural Research and Training (I.A.R&T), Moor Plantation in Ibadan. The I.A.R&T is located in the derived savanna agro ecology of Nigeria (Figure 1).

2.2 TREATMENTS

2.2.1 Water Deficit Stress

(i) No water stress (FW): plots receive water up to field capacity till plant maturity

(ii) Water stress for 14 days (withdrawn of watering) at three weeks after seedling emergence, while normal watering resumed till plant maturity (STR1)

(iii)Water stressed imposed in maize plots by water withdrawer for 14 days at 6 weeks after seedling emergence after which normal watering resumed till plant maturity (STR2).

2.2.2 Fertilizer rates

(i) Three rates of N fertilizer (NPK-20-10-10); 0 N, 50 N, 100 N (kg ha^{-1})

(ii) One rate of *Tithonia* - Poultry Compost (TPC): 10 TPC (t ha^{-1}) (10.7 kg N ha^{-1}),

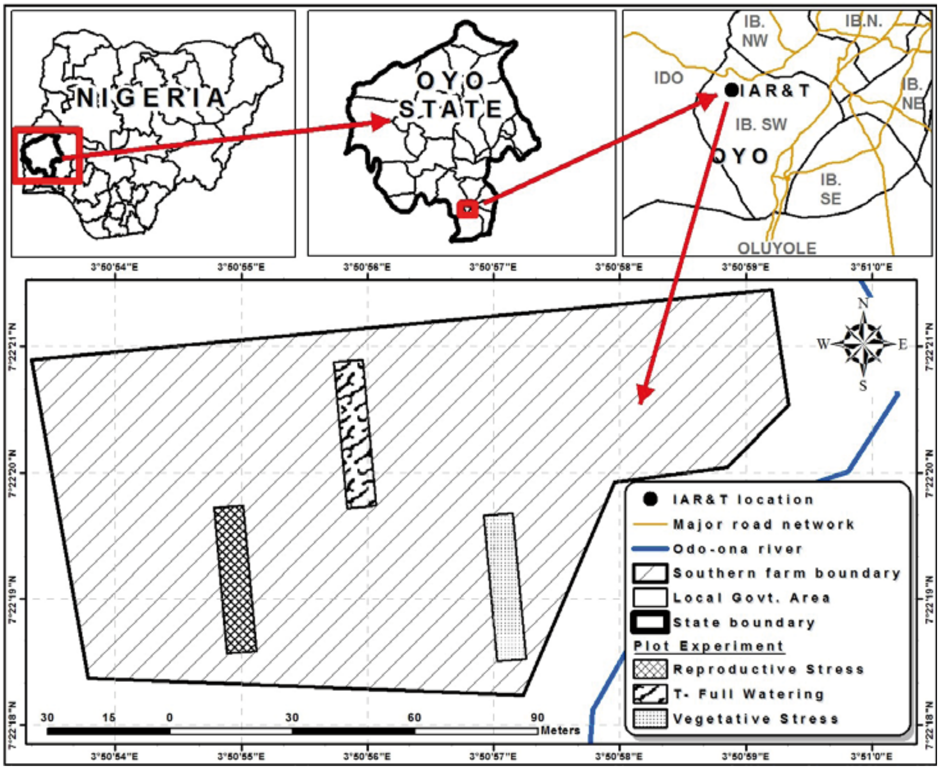

Figure 1: Map showing the experimental plots and location of the experiment at the Institute of Agricultural Research and Training in Ibadan, Oyo state, Nigeria

(iii) Two rates of N fertilizer and TPC combinations; 50 N + 10 TPC and 100 N +10 TPC.

2.2.3 Varieties

Two maize varieties consisting of one quality protein maize variety (ILE-1-OB) and a drought tolerant maize (TZPBSR-W) (Smale et al., 2011) are both open pollinated (intermediate maturing) high yielding characterized by flint texture and white colour seeds, were collected from the seed store of I.A.R & T, Ibadan.

2.2.4 Experimental design

The maize field was planted in 3 x 6 x 2 factorial arrangements using randomized complete block design (r = 3). Each of the three main plots was 27.5 m by 14 m in size were separated by 5 m apart to prevent water seepage across the main plot during irrigation processes, the sub-plot was 4 m x 7.5 m while the sub-sub plot was 4 m x 3.75 m. There were thirty - six plots in the each main plot, each of the sub - sub plot consisted of six (6) rows of two plants per hill at a planting distance of 75 cm x 50 cm inter rows and intra rows spacing, respectively.

2.3 LAND PREPARATION, PLANTING AND CROP MANAGEMENT

The pre crop for both first and second year is maize. The land was prepared mechanically by ploughing and harrowing. Initial wetting was done before each of the operations to ease the operations because the land was very dry and compacted as expected during the dry season. After land preparations, maize seeds were sown at three seeds per hill. The young maize seedlings down to two vigorous healthy seedlings per stand. Pre emergence herbicides (Atrazin® 4 kg ha^{-1} and Glyphosate) were applied to control weeds, while subsequent weeding was done with local hoes.

2.4 COMPOST PREPARATION AND FERTILIZER APPLICATION

The compost was prepared from fresh cuttings of Mexican sunflower (*Tithonia diversifolia* (Hemsl.) using the heap method described by Fernhill, (2011). Nine (9) kilogram of Mexican sun flower (*Tithonia diversifolia*) plant cuttings of about 10 centimeters long were weighed, chopped and spread on the earth surface. The spread plant cuttings were alternated in layers with the spreading of three kilogram (3 kg) of cured fecal poultry droppings to form heap of 1.3 m height. Several heaps made were sprinkled with water before covering with black polythene sheet to increase temperature, moisture maintenance and escape of gases. The heaps were over turned fortnightly with the aid of long garden fork and moisturized adequately to enhance effective microbial growth and activities. Adequate aeration was achieved using 1 m diameter pipes inserted vertically and horizontally into the heaps to ensure adequate ventilation. The pH and temperature were monitored until the compost matured (AAFRD, 2005). The compost heaps were allowed to stay for a period of $2^{1}_{/2}$ months after which the compost materials were ready for use. The compost material was spread thinly on a drying surface under shade and allowed to dry very well before storing in bags. Sample of the matured compost were analysed for chemical properties (Anjorin, 2018). Compost was applied a-week before planting to each of the designated plots to initiate early mineralization of nutrients. Inorganic fertilizer (urea) was applied to the designated plots in splits at two weeks and five weeks after emergence based on the pre - determined rate.

2.5 IRRIGATION

Irrigation was done using sprinklers while tensiometer (Eijkelkamp.co) was used to monitor the soil water potential.

2.6 DATA COLLECTION

- Plant height (using meter rule and measured in centimeter from the base of the plant to the base of the last emerged leaf).

- Leaf area (obtained by measuring in cm^2 using the meter rule to measure the length of a fully expanded tagged leaf and the breadth at mid leaf. The product of the length and the width was multiplied by 0.75 which is the calibration factor for maize leaf (Francis et al., 1969).

- Number of ears per plant (by visual counting)

- Number of rows per cob, number of kernels per row (by visual counting), number of kernels per cob (obtained by multiplying the number of kernels per rows with number of rows per cob), cob length (measuring the length of a cob using the meter rule)

- Grain yield was taken from total ear harvest per plot.

- Mass of 1000 grains and total grain yield (after

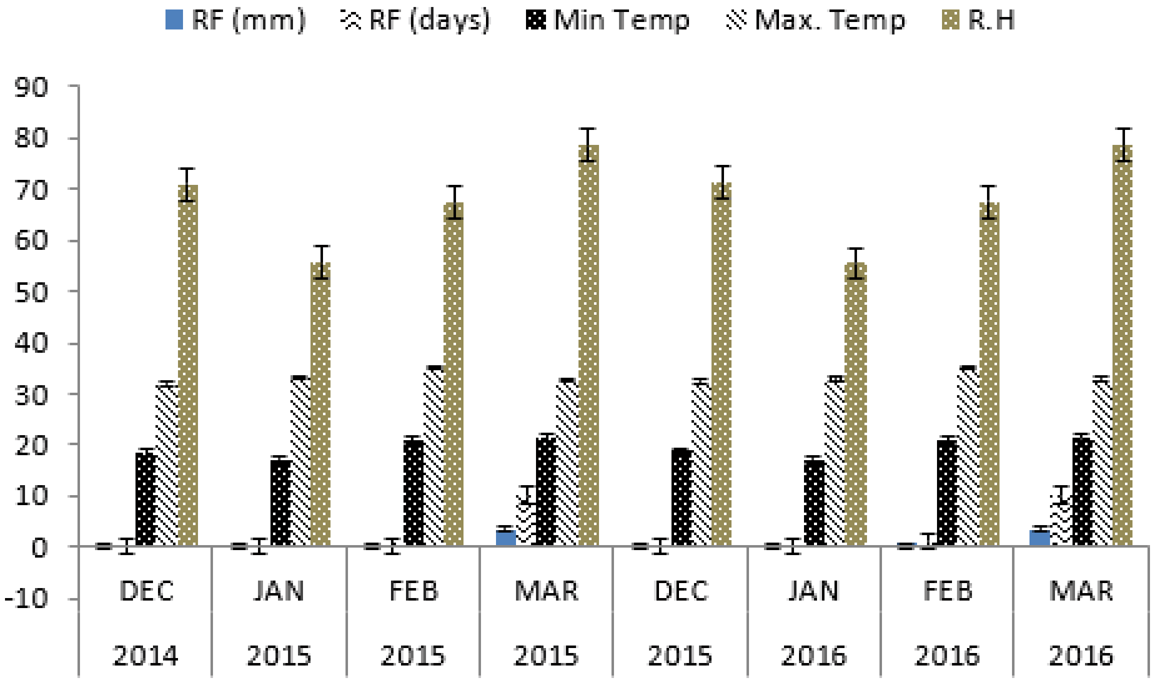

Figure 2: Mean monthly temperature (°C), humidity and precipitation (mm) during 2014, 2015 and 2016 planting seasons. Source: Nigerian Meteorological Agency, Ibadan (NIMET)

adjusting to 12 % moisture content) using weighing balance**.**

2.7 DATA ANALYSIS

The data collected were pooled across the two years and subjected to analysis of variance (ANOVA) for split - split - split plot in RCBD using Statistical Tool For Agricultural Research (STAR, version 2.0.1 2014). Significant means were separated using Tukey Honest Significant Difference at 5% probability level.

3 RESULTS

3.1 WEATHER INFORMATION

The mean monthly temperature (°C), humidity and precipitation (mm) during the experimental studies were shown in Figure 2. No rainfall was recorded for the months of December, January, February (actual periods when water deficit stress was imposed). About 3.43 and 3.49 mm total number of rainfall were recorded in March in 2015 and 2016, respectively. Maximum temperatures were recorded in February while relative humidity values were significantly reduced in January and February of the years of the trials.

3.2 SOIL PHYSICO-CHEMICAL PROPERTIES

The soil obtained from the experimental field was a loamy-sandy soil of classification series "Typic Kanhaplustalf". Result of the chemical analyses showed that there were slight variations in the soil chemical properties in the two years of the experimental studies (Table 1). The pH value of the soil samples appeared slightly acidic in 2015 (6.00) and slightly basic in 2016 (7.25). Soil total nitrogen (0.06 %, 0.05 %), available phosphorus (13.16 mg kg^{-1}, 6.84 mg kg^{-1}), organic carbon (0.44 %, 0.86 %), potassium and the micronutrients were very low in 2015 and 2016 compared with recommended soil requirement for Nigerian soils.

3.3 CHEMICAL PROPERTIES OF COMPOST USED

The compost was slightly basic with pH value of 8.30, total nitrogen content was 0.70 %, while the values of phosphorus and potassium were 0.91 mg kg^{-1} and 0.61 cmol kg^{-1}, respectively (Table 2). The compost had high carbon to nitrogen ratio value (7.47), and very high micronutrients (Iron (9587), Zinc (436) and manganese (597) mg kg^{-1}).

3.4 PLANT HEIGHT (PHT)

Water deficit stress significantly influenced plant height and fertilizer application rates ($p < 0.001$) (Table 3). Significant reduction in plant heights were observed in maize subjected to water deficit stress at three weeks after emergence compared with maize grown under FW and STR2, plant heights ranged from 119.79 cm (STR1) to 150.76 cm (FW) (Table 4). Across the fertilizer rates, maize heights ranged between 116.88 cm (0 N) to 141.18 cm (100 N + 10 TPC), there was no significant difference in the plant heights observed across the fertilizer application rates, except for the control which had relatively shorter plants. Maize variety TZPBSR-W (136.43 cm) are taller than ILE-1-OB (132.01 cm).

Table 1: Pre-planting physico - chemical properties of soil used for the experiments

	2015	2016
Parameter		
pH (H_20)	6.00	7.25
Organic carbon (%)	0.44	0.86
Total nitrogen (%)	0.06	0.05
Available P (mg kg^{-1})	13.16	11.84
Bulk density (Mg m^{-3})	1.31	1.31
ECEC(cmol)	7.11	5.56
Base saturation (%)	99.02	99.28
Exchangeable cation (cmol kg^{-1})		
K	0.22	0.37
Na	0.39	0.63
Ca	5.53	3.80
Al+H	0.07	0.04
Exchangeable micronutrient (mg kg^{-1})		
Fe	7.10	0.06
Zn	3.60	0.65
Cu	1.10	0.15
Mn	22.8	44.10
Soil particle analysis		
Sand g kg^{-1}	854	842
Silt g kg^{-1}	82	86
Clay g kg^{-1}	64	72
Textural class	loamy -Sandy	loamy -Sandy

Table 2: Chemical properties of the *Tithonia* poultry compost used as soil amendment

Parameter	Values
pH (H_20)	8.30
Organic carbon (%)	5.25
Total nitrogen (%)	0.70
Available P (mg kg^{-1})	0.91
C/N ratio	7.47
Exchangeable cation (cmol kg^{-1})	
K	0.61
Na	0.62
Ca	4.95
Mg	0.92
Exchangeable micronutrient(mg kg^{-1})	
Fe	9587
Zn	436
Cu	31.0
Mn	597

Water deficit stress and fertilizer interaction (WS x F) effect on plant height was significant ($p < 0.05$). Plant height ranged from 0 N (99.99 cm) (STR1) to 160.40 cm 10 TPC (FW) (Figure 3a). Plant heights at STR1 across the various fertilizers application rates were not significantly different but higher than 0N (99.99 cm) ($p < 0.05$). Highest plant height was observed at 10 TPC (160.40 cm) (FW) but lowest at 0 N (STR1).

Water deficit stress and variety interaction (WS x V) interaction effect on plant heights was significant ($p < 0.05$) (Table 5). Maize variety TZPBSR-W (160.26 cm) had taller stems under full watering than ILE-1-OB (149.18 cm), however no differences observed in the heights at STR1 and STR2, respectively.

3.5 LEAF AREA (LA)

Leaf area differed significantly across water deficit stress and fertilizer application rates ($p < 0.001$) (Table 3). The leaf areas varied from 458.90 cm^2 (STR1) to 598.81 cm^2 (FW) (Table 4). Across F rates, the largest leaf area size was observed when 100 N + 10 TPC was applied (622.71 cm^2), this LA value was however not significantly different from LA's obtained when 50 N + 10 TPC (611.03 cm^2) and 10 TPC (581.57 cm^2) were applied, while the control (0 N) had least LA size of 397.65 cm^2. The leaf areas of the two maize varieties were not significantly different.

Water deficit stress and fertilizer interaction (WS x F) effect on LA was significant ($p < 0.001$) (Figure 3b). Large leaf area (LA) sizes of maize plant were observed at 100 N + 10 TPC (645.31 cm^2) and 50 N + 10 TPC (647.47 cm^2) under FW. The leaf areas obtained were not significantly different from LA's obtained under 50 N and 100 N and 10 TPC fertilizer applications rates except 0 N (465.11 cm^2). Similar trend was observed in STR2 across the fertilizers application rates. Significant reduction in leaf sizes were observed in STR1 across the fertilizer rates, however considerably larger leaf area sizes were observed with applications of 100 N + 10 TPC (541.47 cm^2) and 50 N + 10 TPC (528.19 cm^2), respectively.

3.6 NUMBER OF EAR PER PLANT (E/P)

The number of ear per plant was not significantly influenced by WS ($p < 0.05$) (Table 3), however the E/P varied significantly across fertilizer application rates ($p < 0.01$). Applications of 100 N + 10 TPC (1.57) and 50 N + 10 TPC (1.60) produced more ear per plant than other F-application rates and the control which had the least value of 1.27 of ear per plant.

Fertilizer and variety interaction (F x V) effects on number of ear per plant of two maize was significant ($p < 0.05$). Maize variety ILE-1-OB (1.39) had fewer numbers of ears than TZPBSR-W (1.15) under the control, maize variety TZPBSR-W (1.55) had more ears than ILE-1-OB (1.35) under 100 N (Table 6).

3.7 COB LENGTH (CBT)

The cob length was significantly influenced by water deficit stress and fertilizer application rates ($p < 0.001$) (Table 3), across WS, the cob length ranged from 12.46 cm (STR2) to 18.02 cm (FW) (Table 4). Cobs length ranged between 0 N (12.02 cm) to 100 N + 10 TPC (16.44 cm). However, no significant difference was observed between cob lengths of 100 N (15.45 cm) and 10 TPC (15.28 cm).

3.8 NUMBERS OF ROWS PER COB (R/C)

Water deficit stress and fertilizer significantly influenced number of rows per cob ($p < 0.001$) (Table 3). The effect of WS on R/C, varied between STR2 (11.83) to FW (13.72), while applications of 100 N + 10 TPC and 50 N + 10 TPC and 100 N had the highest number of rows per cob compared with R/C of other fertilizer applications rates but lowest in the control (11.03) (Table

Table 3: Mean square of ANOVA of the effects of water, fertilizer, variety and result of f-interaction on growth and yield components of two maize varieties evaluated in Ibadan

Source o variation	D.F	PHT (cm)	LA (cm^2)	E/P	CBT (cm)	R/C	K/R	K/C	1000-KM (g)	GY (t ha^{-1})
Rep	2	20.76 ^{ns}	1056.68^{ns}	0.02^{ns}	0.92^{ns}	0.28^{ns}	29.13*	5225.06*	33.68^{ns}	0.88^{ns}
Water Deficit Stress (WS)	2	8751.46***	189971.98***	0.09^{ns}	278.99***	32.93***	1408.25***	383053.62***	7671.47**	128.15***
Error(a)	4	30.48	1193.08	0.18	2.26	0.39	2.20	472.02	96.68	0.66
Fertilizer (F)	5	1549.10***	129468.95***	0.25**	53.88***	16.09***	435.31***	115200.02***	4336.72***	26.16***
WS x F	10	170.81*	7490.99***	0.04^{ns}	2.83^{ns}	0.99^{ns}	16.65**	4302.01**	538.55*	1.50**
Error (b)	30	73.09	1492.64	0.05	1.55	0.50	3.44	1041.12	201.57	0.40
Variety (V)	1	524.92**	4572.76^{ns}	0.00^{ns}	1.45^{ns}	1.05^{ns}	3.35^{ns}	1493.16^{ns}	255.38^{ns}	0.41^{ns}
WS x V	2	217.86*	5150.80^{ns}	0.01^{ns}	1.34^{ns}	0.38^{ns}	6.39^{ns}	1412.44^{ns}	115.18^{ns}	0.51^{ns}
F x V	5	30.39^{ns}	1131.86 ^{ns}	0.08*	1.76^{ns}	0.39^{ns}	4.91^{ns}	1065.81^{ns}	107.53^{ns}	0.57 ^{ns}
WS x F x V	10	30.23^{ns}	1337.78^{ns}	0.021^{ns}	0.67^{ns}	0.74^{ns}	4.14^{ns}	1136.89^{ns}	55.21^{ns}	0.37 ^{ns}
Error (c)	36	54.61	2072.01	0.025	1.30	0.79	4.19	1315.16	115.31	0.34
Total	107									

* ** *** Significant at $p < 0.05$, 0.01, 0.001, ^{ns} = not significant. D.F = Degree of freedom † Means not followed by the same.
Letters within a column are significantly different at P = 0.05 according to Tukey HSD. PHT = Plant height, LA = Leaf area, E/P = Ear per plant, CBT = Cob length R/C = Row per cob, K/R = Kernel per row, K/C = Kernel per cob, 1000-KM = Mass of 1000 kernels and GY = Grain yield

Table 4: Main effect of Water Deficit Stress, fertilizer and variety effect on growth and yield components of two maize varieties evaluated in Ibadan

	PHT (cm)	LA (cm^2)	E/P	CBT (cm)	R/C	K/R	K/C	1000-KM (g)	GY (t ha^{-1})
Water regime									
FW	150.76a	598.81a	1.54a	18.02a	13.72a	30.34a	419.68a	244.73a	6.59a
STR1	119.79c	458.90c	1.46a	14.90b	12.50b	23.05b	292.98b	231.43b	3.92b
STR2	132.11b	562.77b	1.44a	12.46c	11.83c	17.90c	215.33c	215.57c	2.94c
F.rate (F)									
0 N	116.88b	397.65c	1.27b	12.02d	11.03c	15.57c	177.34c	203.78c	2.37c
50 N	132.58a	494.84b	1.51ab	14.64c	12.18b	21.58b	266.72b	222.23ab	3.98b
100 N	133.75a	533.15ab	1.45ab	15.45bc	13.11a	25.57a	337.58ab	233.16ab	4.85ab
10 TPC	140.13a	581.57a	1.49ab	15.28bc	12.82ab	23.33ab	306.96ab	236.01a	4.61ab
50 N + 10 TPC	140.79a	611.03a	1.60a	16.44ab	13.50a	26.69a	362.46ab	246.68a	5.26a
100 N+ 10 TPC	141.18a	622.71a	1.57a	16.91a	13.46a	29.84a	404.92a	241.60a	5.82a
Variety	15.01	67.85	0.27	1.26	0.72	3.26	56.66	15.95	0.78
TZPBSR-W	136.43a	546.18a	1.48a	15.01a	13.14a	23.58a	305.61a	232.13a	4.58a
ILE-1-OB	132.01b	533.65a	1.48a	15.24a	12.77a	23.94a	313.31a	229.05a	4.51a
s_e	1.69	10.45	0.02	0.29	0.14	0.69	11.38	2.17	0.19
Mean	134.22	540.16	1.48	15.12	12.68	23.76	309.33	230.58	4.48

† Means not followed by the same letter within a column are significantly different at $p < 0.05$ according to Tukey Honest Significant Difference. STR 1 = Water stress at vegetative growth stage, STR 2 = Water stress at reproductive growth stage and FW = Full watering, PHT = Plant height, LA = Leaf area, E/P = Ear per plant, CBT = Cob length R/C = Row per cob, K/R = Kernel per row, K/C = Kernel per cob, 1000 KM = Mass of 1000-kernels and GY = Grain yield

4). Interaction effects on number of rows per cob were not significant

3.9 NUMBERS OF KERNELS PER ROW (K/R)

Number of kernels per row varied across the replicates ($p < 0.05$), WS and F ($p < 0.001$) and WS x F (0.01) (Table 3). Effect of WS on K/R was the lowest at STR2 (17.90) but the highest at FW (30.34), across fertilizer application rates (Table 4). Across SA rates, the number of kernel per row also ranged between 0 N (15.57) to 100 N + 10 TPC (29.84), though number of K/R at 100 N + 10 TPC was not significantly different from K/R recorded for 50 N + 10 TPC (26.69) and 100 N (25.57). The number of kernels per row ranged from 0 N (22.64) to 100 N + 10 TPC (34.37) under FW, while no significant difference among K/R formed by the applications of 100 N + 10 TPC (34.37), 50 N + 10 TPC (28.79) and 10 TPC (32.99) (Figure 3c). High significant reductions in number K/R was observed at STR2 and K/R ranged from 0 N (9.76) to 100 N + 10 TPC (24.37) followed by 50 N + 10 TPC (21.59).

3.10 NUMBERS OF KERNELS PER COB (K/C)

The numbers of kernels per cob varied significantly across the replicates ($p < 0.05$), WS and F ($p < 0.001$) and WS x F ($p < 0.01$) (Table 3). Effect of WS on K/C varied from STR2 (215.33) to FW (419.68) (Table 4). Across F-rates, the highest number of kernel per cob was recorded at 100 N + 10 TPC (404.92) and the lowest in the control (177.34), number of kernels per cob at 100 N, 10 TPC and 50 N + 10 TPC were not significantly different. Water deficit stress and fertilizer interaction effect was significant on K/C, least number of K/C was obtained at STR2 (98.86) while application of 100 N + 10 TPC (514.94) gave highest number of K/C at FW.

3.11 MASS OF1000-KERNELS (1000-KM)

The mass of 1000-kernels was significantly influenced by WS ($p < 0.01$), F ($p < 0.001$) and WS x F ($p < 0.05$) (Table 3). The effect of WS on 1000-kernel mass varied from STR2 (215.57 g) to FW (244.73 g) (Table 4). Across the fertilizer application rates, the mass of 1000-kernel was the highest at 50 N + 10 TPC (246.68 g), though not significantly different from 1000-KM of 100 N+ 10 TPC (241.60 g) and 10 TPC (236.01 g), while the control had the least value of 203.78 g.

Water deficit stress, fertilizer interaction effect shows that the highest 1000-kernel mass was obtained at 50 N + 10 TPC under FW (266.13 g), this value was not significantly different from 1000-kernel mass observed at 100 N + 10 TPC (261.38 g), 10 TPC (257.78 g) and 10 TPC (257.50 g), while the smallest value of 1000-kernel mass was observed under STR2 at 0 N (179.10 g). Across STR1, the mass of 1000-kernels were not significantly different.

3.12 GRAIN YIELD (GY)

Grain yield varied significantly at WS, F ($p < 0.001$) and WS x F ($p < 0.01$) (Table 3). The effect of WS on GY ranged between STR2 (2.94 t ha^{-1}) and FW (6.59 t ha^{-1}) (Table 4). Across F- applications, 100 N + 10 TPC (5.82 t ha^{-1}) and 50 N + 10 TPC (5.26 t ha^{-1}) produced the highest GY, while the control showed the least GY (2.37 t ha^{-1}). Application of 8.33 t ha^{-1} (100 N + 10 TPC) under FW

Table 5: Water deficit stress and Variety interaction effect on plant heights of two maize varieties in Ibadan

Water stress	Variety	Plant height
FW	ILE-1-OB	149.18 ± 5.18
	TZPBSR-W	160.26 ± 4.06
STR1	ILE-1-OB	126.03 ± 3.27
	TZPBSR-W	128.90 ± 2.54
STR2	ILE-1-OB	141.80 ± 4.96
	TZPBSR-W	139.76 ± 4.42

STR 1 = Water stress at vegetative growth stage, STR 2 = Water stress at reproductive growth stage and FW = Full watering

Table 6: Variety and fertilizer application rates interaction effects on number of ear per plant of two maize varieties in Ibadan

Fertilizer	Variety	Number of earper plant
0 N	ILE-1-OB	1.39 ± 0.08
	TZPBSR-W	1.15 ± 0.06
50 N	ILE-1-OB	1.52 ± 0.06
	TZPBSR-W	1.49 ± 0.11
100 N	ILE-1-OB	1.35 ± 0.05
	TZPBSR-W	1.55 ± 0.06
10 TPC	ILE-1-OB	1.43 ± 0.07
	TZPBSR-W	1.54 ± 0.08
50 N + 10 TPC	ILE-1-OB	1.64 ± 0.11
	TZPBSR-W	1.55 ± 0.07
100 N + 10 TPC	ILE-1-OB	1.58 ± 0.06
	TZPBSR-W	1.57 ± 0.07

produced the highest GY, while GY was the lowest at 0 N under STR2 (0.88 t ha^{-1}) (Figure 3f). The GY of the two maize varieties were not significantly different ($p < 0.05$).

4 DISCUSSION

Drought and low soil fertility are major abiotic factors militating against profitable maize production in the tropics. The use of drought tolerant crop genotypes and soil amendment has potential to enhance growth and yield performances of crops grown under drought condition. To investigate the role of soil nutrient amendment on the growth and yield responses of crop to water deficit stress, field experiment was established in Ibadan, Nigeria.

Results obtained show that 14 days withdrawal of watering during the vegetative growth stage (STR1) resulted in maize plants with reduced heights and leaf areas. The reduction in leaf area as a result of water deficit stress may be attributed to decrease in rate of leaf initiation and expansion and or accelerated rate of leaf senescence and leaf shedding which consequently reduce grain yield compared with grain yield obtained under well watered condition (Bolaños & Edmeades, 1996; Nam et al., 1998; Anjum et al., 2011). As leaves with reduced leaf area do not fully intercept solar radiation which in turn strikes the ground, and consequently increased the evaporation - transpiration ratio (Araus, 2002). Reduction in plant height from water deficit stress interferes with over all crop photosynthetic efficiency (Imadi et al., 2016). Hence, plants with greater heights are often larger in overall plant size, intercept more light and use water faster by transpiration.

In this study, water deficit stress at vegetative stage (STR1) accounted for 41 % loss in grain yield, this finding agreed with the report of Rufino et al. (2018). Water deficit stress affects all the various metabolic processes and yield components in plant and in turn reduced crop yield potential. Borra's et al. (2003), inferred that the overall indirect impact of water stress during vegetative stage on grain yield is source limiting as water stress decreased the source potential and available assimilates level and decreases grain weight. For instance, the kernel rows in maize are determined between V7 to V8 maize growth phase, while the number of kernels on each ear and size of ear in maize is determined at V12 of the maize growth stage (Ritchie & Hanway, 1993; Annonymous, 2013). Therefore, occurrence of water deficit stress during vegetative growth phases becomes detrimental to

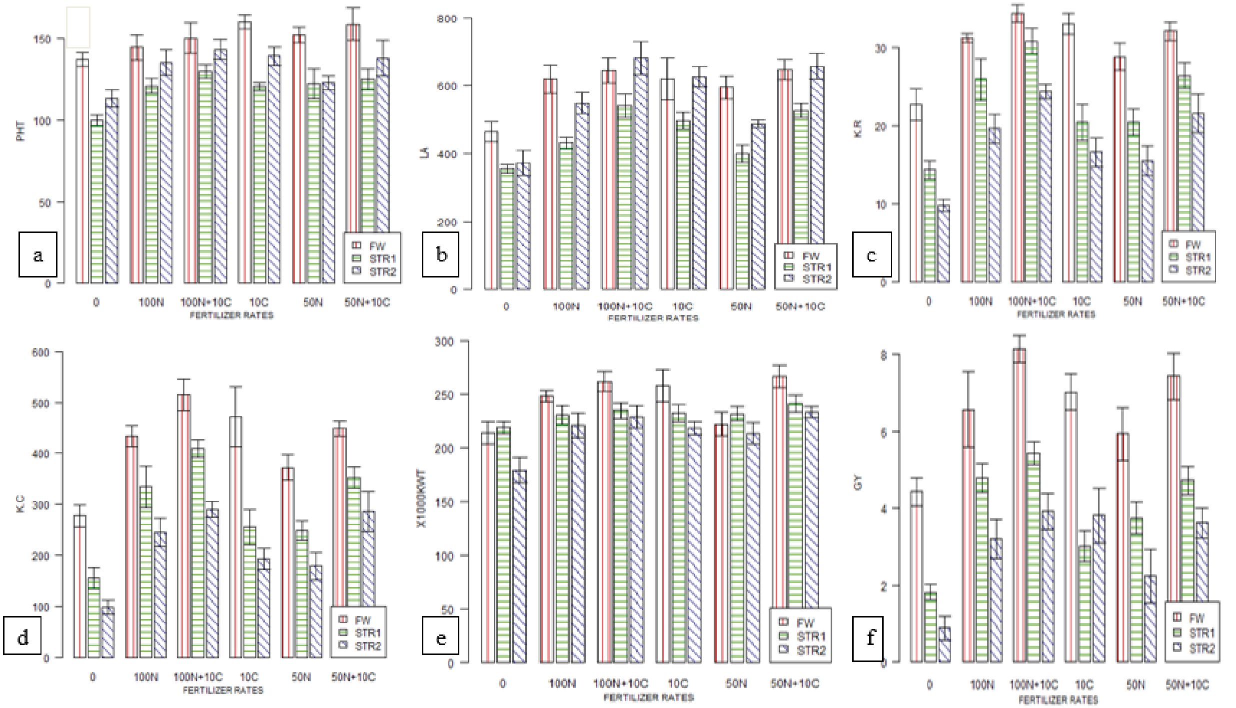

Figure 3: Water deficit stress and fertilizer interaction effects on (a) PHT (Plant Height) (b) LA (Leaf Area) (c) Number of K/R (Kernels/Row), (d) K/C (Kernels/cob), (e) 1000-Kernel weight and (f) GY(Grain Yield) of two maize varieties planted under three water deficit stress and six fertilizer application rates in Ibadan. FW = Full watering, STR1 = Water stress at vegetative growth stage STR 2 = Water stress at reproductive growth stage

the final crop grain yield (Ritchie & Hanway, 1993). This is because, water deficit stress during vegetative growth stage decreases plant source potential and assimilates level thereby decreasing grain weights (Borra's et al., 2003; Fatemi et al., 2006 and Khalili et al. 2010)

The impact of preanthesis water deficit stress (STR2) in this study resulted in 55.37 % loss in grain yield, this finding agreed with the reports of Denmead & Shaw, (1960) and Sah et al. (2020). Farre & Faci, (2009), and Mansouri, et al. (2010), which earlier inferred that grain yield of maize is highly determined by the amount of irrigation water. The number of ear formed per plant were not significantly different across the water deficit stress regime, but ears obtained from plants subjected to preanthesis water deficit stress (STR2) were smaller in size with few grains while some were even barren. The significant reduction in the number of grain per row and 1000-kernel weight under the water deficit stress observed in this study agreed with the earlier reports of Carpici (2009) and Kuscu (2010). In the view of Grant et al. (1989) and Hargurdeep & Westgate (2010) water deficit stress during pre anthesis stage of maize development could be implicated for abnormal development of embryo sac, grain sterility and decreased fertile grain number. While imposition of water deficit stress during preanthesis growth stage resulted in reduced number of kernels per cob, kernel set per row and the total grain yield (sink limiting).

Increased fertilizer applications significantly enhance R/C, K/R, K/C, Weight of 1000-kernels and GY across the water deficit stress regime in this study. Deficiencies in N supply have been reported to impair pollination synchronization, increased kernel abortion (Uribelarrea et al., 2002; Uhart & Andrade, 1995), resulting in reduced kernel number per plant and decrease grain yield observed in the fertilizer control (Carcova et al., 2000; Paponov et al., 2005). Apart from water, soil nutrient especially nitrogen also had significant impact on the yield components and grain yield of maize in this study. Increased maize growth and yield responses were obtained under increased fertilizer application rates especially when 10 t ha^{-1} of compost was added to each inorganic fertilizer rates of 50 and 100 kg ha^{-1} respectively. Application of inorganic fertilizer with compost to crop has been reported to have the advantage of providing nutrients to meet crop nutrition requirements and maintain soil health (Abedi et al., 2010; Kazemeini et al., 2010; Efthimiadou et al., 2010). High level of micronutrient in the compost (Table 2) may have helped to improve general plant performance. Apart from water, soil nutrient especially nitrogen also had significant impact on the growth and yield components of maize in this study.

Application of nitrogen fertilizer have been shown to increased the uptake of other nutrients, this is because nitrogen enhances growth and development of small roots and root hairs which in turn facilitate the absorbing ability per unit of dry weight (Gheysari et al., 2009; Hammad et al., 2011). Nitrogen is also needed to establish and maintain the enzymatic processes essential for carbon utilization and growth, and is also a major constituent of endosperm storage protein (Cazetta et al., 1999; Duvnjak et al., 2021). The use of 10 t ha^{-1} of Tithonia poultry compost in combination to each of 100 kg N ha^{-1} and 50 kg N ha^{-1} of nitrogen fertilizer significantly enhanced grain yield than sole applications of each of inorganic fertilizer rate in this study. The compost (Table 2) has a very high carbon to nitrogen ratio, also very rich in essential micronutrients needed for maize production. Application of inorganic fertilizer with compost to crop has been reported to have the advantage of providing nutrients to meet crop nutrition demands and maintain soil health (Efthimiadou et al., 2010). Compost had been reported to improve soil water holding capacity as well as buffering rapid changes in soil pH (Tambone et al., 2007; Zemánek, 2011).

The significant water regime by fertilizer interaction effects on the various growth and yield components in this study indicated that growth and yield increased resulting from fertilizer application depended on the availability of water (Pandey et al., 2000). Hence, adequate moisture availability is vital to nutrient mineralization, growth and grain yield of maize (Hokmalipour et al., 2010). Water deficit stress at the vegetative stage of growth not only deprived the plant of adequate moistures supply needed for cellular meristematic activities but also hinder nutrient supply which are needed for the development of yield component potential. Despite the impact of the water stress on the various yield components of maize, increased application of fertilizer was seen to enhanced grain yield of the two maize varieties. Increased nitrogen application has been shown to have the capability of improving drought tolerance and enhancing grain yield in maize (Boutras, 2001; Xu et al., 2005). Variety TZPBSR-W appeared to performed better than ILE-1-OB most especially under well watered condition but such superiority could not be maintain under the first and second water stress conditions as observed in the number of kernels per row and number of kernels per cob. The effect of water stress on seed formation, kernel set and grain yield was most severe during the reproductive growth stage and under reduced nutrient availability. Water stress and low nutrient availability might have reduced the sink strength and capacity of the maize plants which are determined by genetic and environmental factors (Alvarez Prado et al., 2014).

Moisture availability and nutrient availability to a large extent, determines seed formation, kernel set, and the final grain yield in this study. Nitrogen fertilizer effect on the various yield components and grain yield improved as the N application increases. Maize plant performed best when inorganic fertilizer was used along with organic fertilizer than when organic or inorganic fertilizer was applied alone. The result of the present finding on water regime nitrogen interaction also revealed that growth and yield components and grain yield performed better under adequate moisture availability. Nitrogen had been reported to improve water use efficiency in maize (Ogola et al., 2002). Growth and yield components were improved with increase N application even under water stress conditions. Therefore, optimization of N and water management could be an efficient way to attain sustainable agriculture. The two maize varieties were similar in yield responses to the varying stress periods and fertilizer application rates in the two years of the experimental studies. Similar report of variability in crop genotypic response under water stress had earlier been reported by Hufsteler et al., (2007); Abayomi & Abidoye, (2009).

Application of 10 t ha^{-1} of *Tithonia* poultry compost alone to the maize field produced taller maize plants and broader leaves better than maize plants obtained when 100 kg N ha^{-1} inorganic fertilizer were applied, but this alone could not sustain the plant adequately beyond the pollination process. The evidence of this was the rapid appearance of yellow lower leaves in treatment with 10 t ha^{-1} (*Tithonia* poultry compost alone). Explanations for this could be that the N supply by the compost alone at the transition stage from vegetative to reproductive was not adequate enough for N demand for post pollination activities. Hence the need for remobilisation of N from the lower leaves for grain filling was inevitable.

5 CONCLUSION

Climate change and its associated attributes have impacted negatively on general crop development across the world. Drought emanating from erratic rainfall pattern has constituted serious menace to profitable maize production in the sub Saharan Africa. From this study it was obvious that water deficit stress reduced growth and yield performances of the two maize varieties resulting into grain yield losses of 41.0 % and 55.37 % under vegetative and reproductive stages water deficit stresses, respectively. However, this study has been able to explore soil fertility management at enhancing growth and yield performances of maize subjected to water deficit stress. Different rates of nitrogen fertilizer from inorganic, organic sources and their combinations were applied to the two maize varieties at different phenological growth –water deficit stages. From the result, it is obvious that 50 kg N of inorganic fertilizer and 10.7 kg N of *Tithonia* Poultry Compost significantly enhance growth and yield performances of the two maize varieties across water stresses in this study. The 50 kg N of inorganic fertilizer represents half dose of recommended 100 kg N of nitrogen fertilizer (inorganic) application rate for the agro ecological zone of the country. Minimal use of inorganic fertilizer rate will help reduce environmental issues associated with the increase use of chemical fertilizers and cost of production. The maize varieties grown under 50 kg N ha^{-1} NPK-20-10-10 and 10.7 kg N ha^{-1} TPC subjected to water deficit stress must have benefited immensely from fast release of plant nutrient (inorganic fertilizer) with high; micronutrients, organic carbon content and moisture retention of compost. Augmenting reduced rate of inorganic fertilizer with *Tithonia* compost is hereby recommended for profitable maize production in derived savanna ecology of Nigeria. In spite of the numerous benefits associated with the use of compost, the bulkiness and availability of enough quantities for large scale maize production remains a great challenge. Farmers should be adequately trained on compost preparation techniques and the importance of combine use of inorganic and organic fertilizers to boost maize production in the face of the prevailing climate change. Government should support and empower unemployed youth to embrace commercial compost production so as to cater for the anticipated high compost demand by commercial farmers. More funding should be made available for soil fertility management and climate change adaptability studies.

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