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YIELD AND GROWTH RESPONSE OF SWEET CORN (*Zea mays saccharata*) TO WATER STRESS REGIMES ON A LOAMY SAND SOIL

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ABSTRACT

Maize dry season production is often confronted with soil moisture, pest diversity and environmental stress that becomes obvious in plant stress. Therefore, the amount of stress that a plant can withstand depends on soil type and evapo-transpiration demand of the atmosphere. Thus an experiment was carried out to assess the effects of varying levels of water stress on the growth and yield of sweet corn on a loamy-sand soil. For this purpose, Crop-Environmental Water Demand (CEWD) was developed from daily evapo-transpiration records and FAO crop water requirements for different stages of maize growth, based on the average weather data for a decade (2001 - 2011). Soil requirement for growing maize in the area was also noted. A tropically adapted sweet corn population was grown under four water application rates ranging from 25 % to 100 % CEWD in a randomized complete block design with three replicates. The results showed that there was significant difference in plant growth for the four treatments imposed as the increase in soil moisture level influences plant development. Differences among the treatments number of grains per plant were significant. Sweet corn grain yield was in the order of 75 % > 100 % > 50 % > 25 % CEWD. Significant differences were not observed for flowerings dates and number of leaves. Mean plant height was closely related to the rate of water application and ranged from 0.65m - 1.2m across the treatments. Seventy-five percent CEWD treatment plots had the highest total dry matter content and leaf area index which explain the significant differences observed in the grain yield. Application of 75 % CEWD on sweet corn significantly influenced the growth and yield of sweet corn on loamy-sand soil. Water application rates at 25 % less full CEWD was adequate for dry season sweet com production on loamy-sand soil in Ibadan, Nigeria.

Key words: CEWD, sweet corn, soil moisture stress, water

INTRODUCTION

Sweet corn (*Zea mays convar. saccharata, var. rugosa*) is a variety of maize with high sugar content (Hirich *et al*., 2012). It is the result of a naturally occurring

recessive mutation in the genes which control conversion of sugar to starch inside the endosperm of the corn kernel. Sweet corn originated in South America and cultivated by Native Americans long before arrival of Europeans, it is one of the most popular vegetables in the United State and its popularity is growing rapidly all over the world (Anonymous, 2001; Lucier and Lin, 2001). However, Vegetables can be described as food of plant origin usually herbaceous annuals or perennials whose consumable parts can be eaten raw or cooked and serve as a source of vitamins, proteins and minerals (Akintoye, 2002), Unlike field corn varieties, which are harvested when the kernels are dry and mature (dent stage), sweet corn is picked when immature (milk stage), prepared and eaten as a vegetable, rather than as a grain (Schultheis, 2010).

According to Mann (2009), it is traditionally eaten with beans in Latin America, a combination which forms a balanced staple food in West and Central Africa (WCA) as it is an important source of fiber, minerals and certain vitamins such as Vitamin C, B-complex and A (Lucier and Lin, 2001). In Europe, China, Korea, and Japan, sweet corn are used as a pizza topping, or in salads (Mann, 2009; CornellNews, 2011).

Sweet corn grows well on almost any well-drained soil with adequate organic matter and soil pH of 6.5-8.0 (James, 2001; Schultheis, 2010)."It requires at least 24.7 mm of water per week when temperatures are warm and growth is rapid (Schultheis, 2010) and successful early plantings can best be achieved by planting on sandy soils that warm early (Mann, 2009). Several biotic and abiotic constraints affect maize production. The dominant biotic constraints are diseases, pests and weeds while abiotic constraints include water stress (drought) and low or declining soil fertility (Edmandes *et al*., 2001).

Soil moisture is generally available from rain, stream or river, and ground water, the supply of which varies both in terms of distribution (Gleick, 2010; Schultheis, 2010). Crops response to climate variability depends mainly on the growth stage of the crop at the time of weather aberration. According to Hirich *et al.* (2012), short term weather fluctuations especially rainfall and temperature affect

growth and yield of maize. To ensure adequate moisture in soil for optimum plant growth and yield, irrigation procedure based on the crop, water and soil relationship is required.

It thus becomes imperative to produce food with less water than was previously available. Therefore, deficit irrigation – a strategy that attempt to use less water but conserve economic returns, could be adopted in the face of the present situation (Owusu-Sekeye and Andoh, 2012).

Also, producing food for the 6.5 billion people or more who inhabit the planet today require water that would fill a canal ten meters deep, 100 meters wide and 7.1 million kilometers long – that's enough to circle the globe 100 time (UNEP, 2002) with significant proportions in more economically developed countries such as United States, where about 30% of freshwater usage is for irritation (Gleick, 2010).

The extent to which plants, especially corn can withstand moisture stress depends on soil type and Evapo-Transpiration demand (ET) (Fereres and Soriano, 2006). Evapo-transpiration (ET) contributes to environmental water loss from soil and from part of water cycle (Kulshrestha, 1998). Approximately, 70% of the fresh water used by humans goes to agriculture (UNWWD, 2008) while in United State 30% of freshwater usage is for irrigation. Forces acting on the soil water decrease its potential energy and make it less available for plant root extraction. When the soil is wet, the water has a high potential energy, is relatively free to move and is easily taken up by the plant roots. In dry soils, the water has a low potential energy and is strongly bound by capillary and absorptive forces to the soil matrix, and is less easily extracted by the crop (FAO, 1998). When the potential energy of the soil water drops below a threshold value, the crop is said to be water stressed.

Thus, the need to understand the influence of water scarcity on the production of sweet corn that is gaining rapid popularity in the WCA (Sub-Saharan Africa) and environment such as in Ibadan which is prone to climate change is of great importance. However, some observers have estimated that by 2025 more than half of the world population will be facing water-based vulnerability (UNEP,

2002). A recent report (November, 2009) suggests that by 2030, in some developing regions of the world, water demand will exceed supply by 50%.

Therefore, to meet the acute freshwater challenges facing humankind over the coming 50 years and to fulfill the food security to feed 8-9 billion people, directing all the efforts to improve water use and management in agriculture is a necessity. Hence, the focus of this study was to determine the effects of water stress on growth and yield of sweet corn and the water requirement for sweet corn development on a loamy sand soil in Ibadan.

MATERIALS AND METHODS

Description of Experimental Location

The experiment- yield and growth responses of sweet corn (*Zea mays saccarata*) to water stress on a loamy sand soil was conducted at University of Ibadan Organo-mineral Fertilizer Demonstration Plant along Barth Road, Latitude 7° 26'N and Longitude 4° 54'E. The site has a mean altitude of 234 m above sea level. The rainfall pattern is bimodal with average of 1230 mm per annum (Oshunsanya, 2010). There are two growing seasons; a wet season runs from March to October and dry season from November to February.

Land Preparation

The field was manually cleared with cutlass and hoe after initial soil sampling. Soil was used to raise each side of the bed to make the bed sunken. This was done to reduce run-off and soil erosion while the inner parts were flat for free water percolation and partition to ensure adequate water uptake by plant root.

Experimental design and Field layout

The experiment was design in a randomized complete block (RCBD) with 3 replicates and four treatments which are 100 %, 75 %, 50 % and 25 % of crop-environmental water demand. The test crop was sweet corn (*Zea mays covar, saccharata, var, rugosa*) Ex-IITA source from International Institute of Tropical Agriculture (IITA). Each plot size was $9m^2$ ($9000000mm^2$) to make sunken bed to

prevent run-off and erosion while each planting line was mound to ensure that water reach the rooting zones alone.

Soil Sampling and Laboratory Analysis

Soil samples were taken on each plot which was later bulked to form a composite. Core samples were equally taken to determine soil bulk density, saturated hydraulic conductivity and permeability. Routine soil analysis was carried out before the commencement of the experiment. Bulk density (core method) was estimated by dividing the oven dry mass of the soil at 105^0C by the volume of the soil as:

Pb = Ms/Vb

Where Pb is the bulk density, Ms is oven dry mass of the soil and Vb is the volume of soil in the core, total porosity was estimated as:

TP = (1-Pb/ Ps) x100

Where Pb is the bulk density and Ps is the particle density given as 2.65gcm^{-3}. Particle size analysis was determined using Bouyoucous Procedure. Soil textual triangle (USDA) was used to determine soil textural class.

Saturated hydraulic conductivity (K_Q) was determined by constant head method above undisturbed core sampler (Oshunsanya, 2011). A flask of water was inverted above the core containing water in other to maintain constant head of water. The quality of water (Q) drained in every 5 minutes was measured until equilibrium (constant through of water is reached). Permeability was calculated from saturated hydraulic conductivity as follows:

$Ks = K_Q \int / e_w g$

Where:

Ks = Permeability (cm^2)

e_w = Density of water (1 g/cm^3)

g - Acceleration due to gravity (980 cm/sec)

$\int$ = Viscosity at 27°C (0.00855 g/cm/sec)

K_Q = Saturated hydraulic conductivity (cm/sec)

Soil chemical parameters determined are:

Soil pH: 10 mls of water was added to 10 g of air dry soil weight (1:1) and stirred inside the plastic bottle with the aid of glass rod. Electrode pH meter was then inserted to read the soil pH in water.

Organic carbon (C): was determined using Walkley Black method.

Total nitrogen (N): was determined using Macro Kjedahl Method that involves digestion, distillation, condensation and titration.

Phosphorous (P): was determined using Mehlich III multipurpose extractant and Atomic Adsorption spectrometer machine was used to read the value.

Potassium (K): was determined using flame photometer as well as extractable micronutrient (mg/Kg) and exchangeable bases (cmol/Kg).

Irrigation Procedure

The Crop-Environmental Water Demand (evapo-transpiration demand) of the area was determined using the weather data for Ibadan within the period often years (2001 -2011) develop from daily evapo-transpiration records and FAO crop water requirements for different stages of maize growth which is 5mm depth of water. Therefore, using the formula below:

Depth (mm) = Volume (cm^3) / Area (m^2)

Water Application was 90 litres per plot at 2 days' interval for field saturation (Evapo-transpiration determination using weather data). Sweet com seeds were sown on 23rd February, 2012 with the spacing of 75 cm x 25 cm. The rate of water application commenced two weeks after planting which was shown on Table 3.6.1. The irrigation water was applied using a watering can.

Fertilizer Application and Weeding

Fertilizer application was done at 2 weeks and 6 weeks after sowing at the recommended rate of 60 kg Nitrogen (N), 30 kg Phosphorus (P_2O_5) and 30 kg Potassium (K_2O) (60:30:30 (NPK)}, 15:15:15 NPK fertilizer and urea 45 kg N was used. The fertilizer was applied on drill lines about 5-7 cm away from the plant.

The weeding was manually done with hoe at 5 weeks while rouging was done at regular interval until maturity.

Data Collection

Data collected include on the following: Growth parameter - Plant height (cm), Number of leaf per plant, Leaf area index (LAI). Yield parameters are days to 50 % and 100 % tasselling and Silking, number of cobs per plot, grains per cobs and weight of grains (fresh and dry) (kg/ha).

Leaf area index was determined using equation below.

LAI = Leaf area (m^2) of plant sampled/plot / Spacing (0.75 m X 0.25m)

The leaf area was determined by multiplying each leaf length and breadth of sampled plant by 0.75. Plant sample were oven dried to constant weight at 70 °C for 72hours. Dry weight of plant samples was obtained with sensitive scale measuring to0.01 g.

Statistical Analysis

All data were subjected to analysis of variance (ANOVA) using Genstat Discovery Edition 3 (VSNI, 2008) and means were separated using least significant difference.

Table I. Water application after sowing

Crop-environmental water demand (%)	Water application/ 2days (litres)
100%	90.0
75%	62.5
50%	45.0
25%	22.5

RESULTS

Pre-planting physical and chemical properties of soil used for the experiment

The textural class (USDA) of the soil was loamy sand, with the sand content- 870 g/kg, silt content- 87 g/kg and clay content- 83 g/kg. Saturated hydraulic conductivity (cm/s) was 4.48 X 10^{-3}while Permeability was 3.9 X $10^{-7}$$cm^2$and the total porosity (%) was 49. These data indicate well aerated and well-drained soil which indicates the field will support adequate soil moisture level for plant growth. The bulk density of the soil is 1.34 kg/m3 with pH (H_2O) 6.1- slightly acidic. The nutrient status of the soil indicated by total nitrogen, N (g/kg) were 1.6, phosphorus (P_2O_5) was 28.0 mg/kg, organic carbon C 14.3 g/kg and potassium (K_2O) was 0.3 cmol/kg, Other exchangeable bases and micronutrients were sodium (Na) 0.6 cmol/kg, Magnesium (Mg_2O) 2.8 cmol/kg, Calcium (Ca) 30.8 cmol/kg, Iron (Fe) 165.2 mg/kg, Manganese (Mn_2O) 354.2 mg/kg and Zinc (Zn) 13.5 mg/kg respectively. All the above results presented in table III (pre-planting physical and chemical properties used for the experiment) show ability of the field to support plant growth and yield.

The trend of water stress regimes on sweet corn leaf area index is presented in Figure 1. The statistical analysis shows that there was no significant difference in treatment imposed on sweet corn leaf area index at 14 and 28 days after sowing. However, at 42 to 56 days after sowing significant differences were observed on the sweet corn leaf area index. Both 75 % and 100 % CEWD treatments sweet corn had greater leaf area index than 25 and 50 % CEWD treatments at 70 and 84 days after planting. These did not only indicate higher ground cover capability across the treatments in ascending other of soil moisture availability but also express high food reserve in the same other. However, 75 % CEWD had higher leaf area index than 100 % CEWD at 70 and 84 days after sowing.

Table II. Pre-planting chemical and physical properties of soil used for the experiment

Parameters	Values
pH(H_20) 1:1	6.1
Exchangeable Bases (cmol/kg)	
K	0.3
Na	0.6
Mg	2.8
Ca	30.8
Extractable Micronutrient (mg/kg)	
Fe	165.2
Mn	354.2
Zn	13.5
Total N (g/kg)	1.64
Org. Carbon (g/kg)	14.3
Available P (mg/kg)	28.0
Particle Size Distribution (g/kg)	
Sand	830
Silt	87
Clay	83
Textural Class (USDA)	Loamy sand
Bulk Density (kg/m^3)	1.34
Saturated hydraulic conductivity (cm/s)	4.48×10^{-3}
Permeability (cm^2)	3.9×10^{-7}
Total porosity (%)	49

Plant growth as influenced by water stress regimes

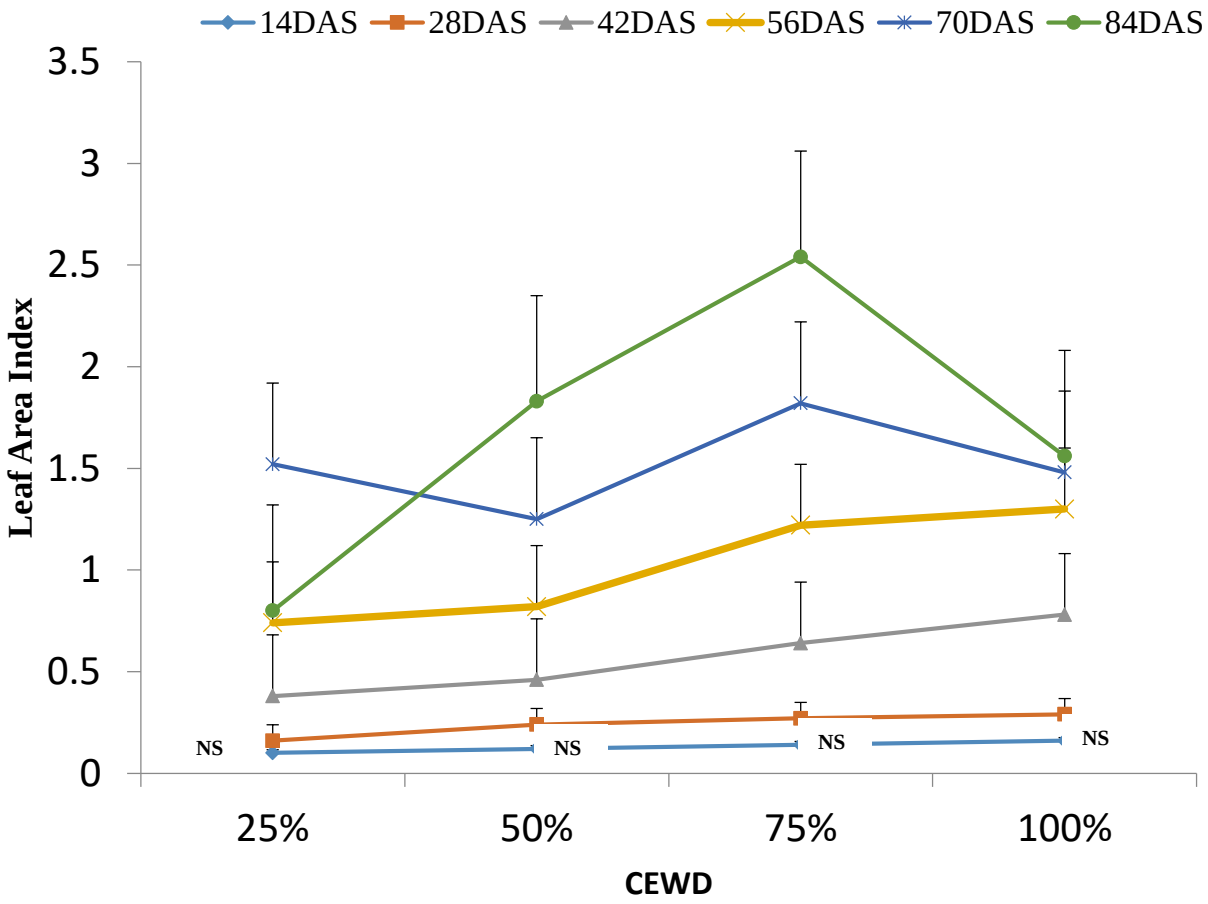


Figure 1: Trend of water stress on sweet corn leaf Area Index

NS: Not significant; DAS: Days after sowing; 25%, 50%, 75%, and 100%: crop-environmental water demand (CEWD).

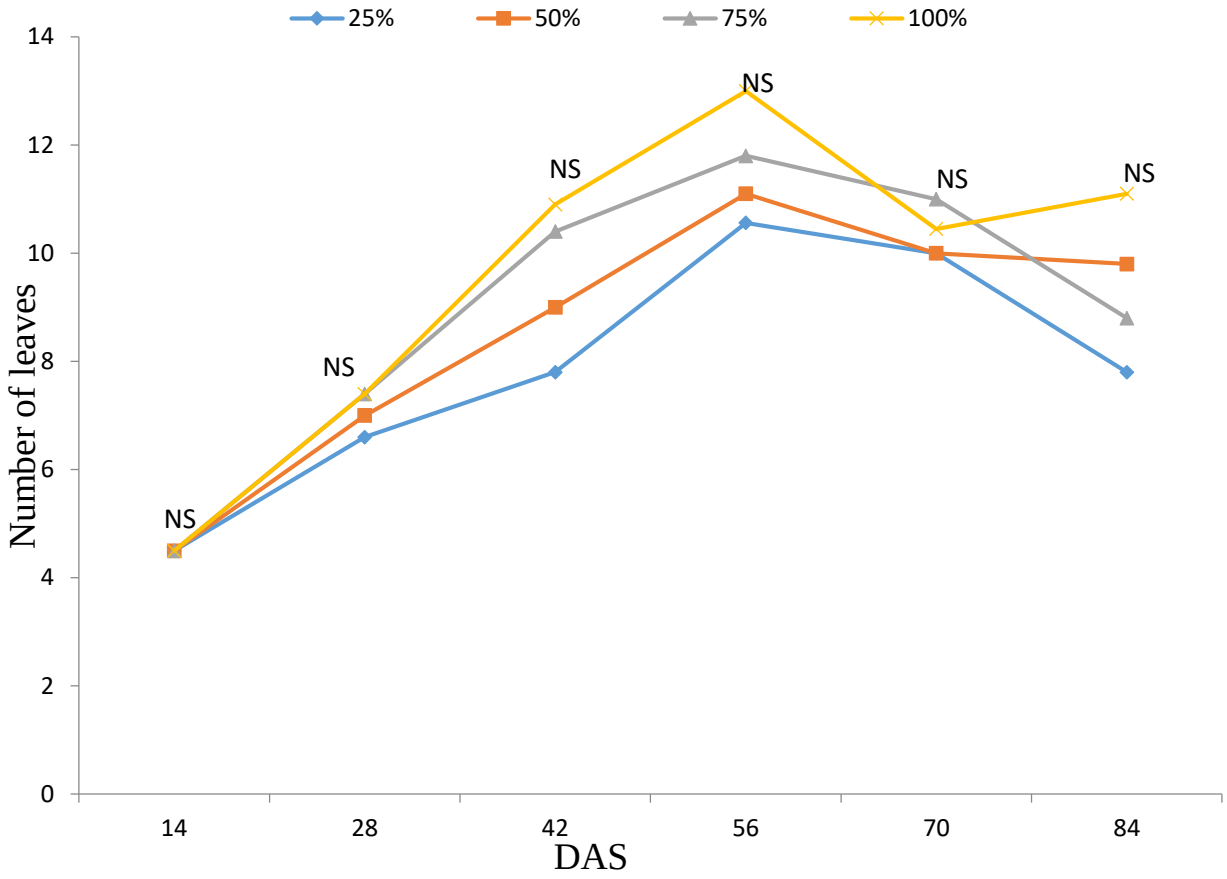


Figure 2: Trend of water stress on sweet corn Number of leaves

NS: Not significant; DAS: Days after sowing; 25%, 50%, 75%, and 100%: crop-environmental water demand (CEWD).

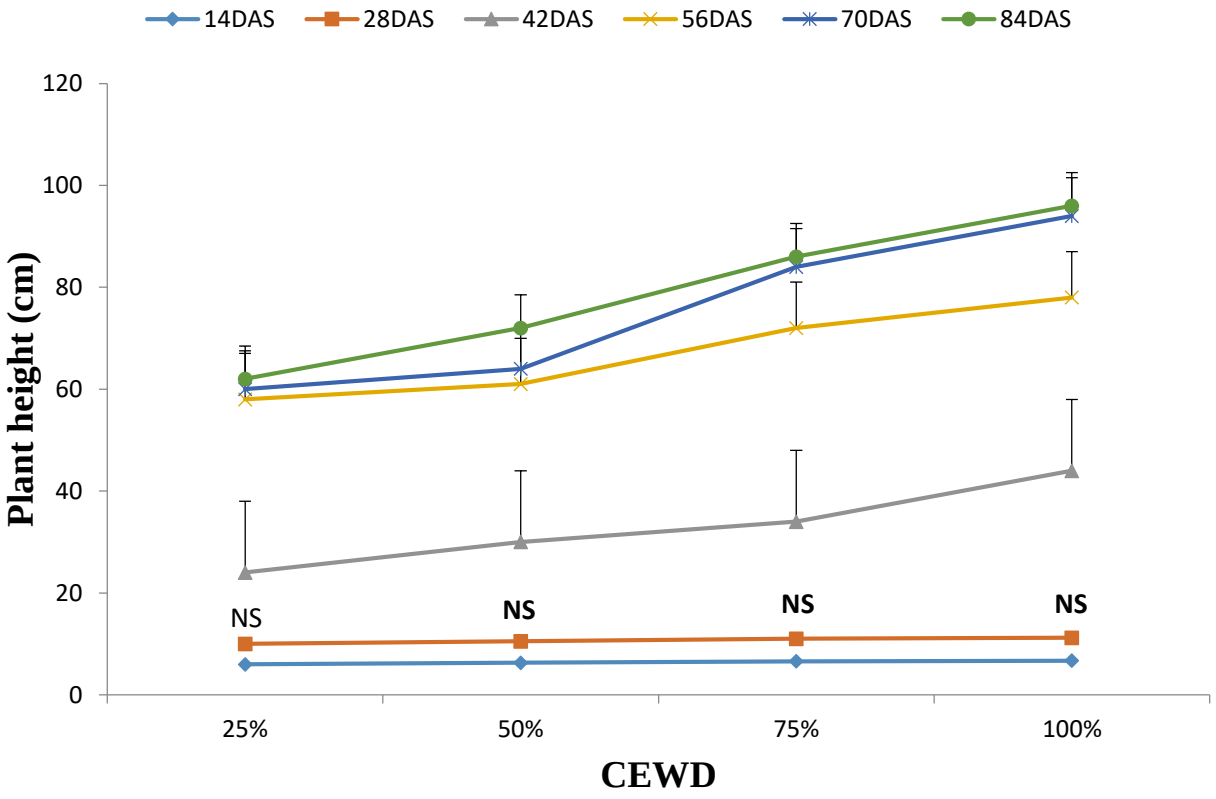


Figure 3: Trend of water stress on sweet corn Plant height (cm)

NS: Not significant; DAS: Days after sowing; 25%, 50%, 75%, and 100%: crop-environmental water demand (CEWD).

There was no significant difference between leaf area index of sweet corn in 75 % and 100 % CEWD at 56 days after sowing but both performed better than 25 % and 50 % CEWD sweet corn.

Also, the effect of water stress regimes on number of leaves is shown in Figure 2. The analysis of the result shows that no statistical significant differences in treatment imposed on sweet corn number of leaves was observed. At 14 days after sowing the number of leaves of sweet com tn alt the treatment plots were 5 while at 56 days after sowing all the treatment sweet corn number of leaves were differences with 100 % CEWD field having the highest number of leaves. The result shows drop in the sweet corn number of leaves at 70 days after sowing as the 75 % CEWD had the highest number of leaves which is the same as that of 100 % CEWD. This period indicated attainment of source and sink stage.

Presented in Figure 3 was effect of water stress regimes on sweet com plant height (cm). The treatment imposed on sweet corn plant shows no significant difference at 14 days after sowing according to statistical analysis while significant differences were observed in sweet com plant height across the treatment from 28 to 84 days after sowing. The highest plant height was obtained at 100 % CEWD plot. This indicated that plant height increases with high soil moisture. Linear trend was observed in all the treatment as shown on the result presented from 28 to 84 days after sowing. The plant height is in order of 100 % > 75 % > 50 % > 25 %. The mean average plant height ranges from 0.6 m to 1.2 m.

Table IV shows the effects of water stress regimes on growth and yield of sweet corn at harvest. The growth parameters considered at harvest also include number of leaves, leaves dry weight, stem dry weight, tassel dry weight and total dry weight. The yield parameters considered were cobs per plant, grains per plot, cob fresh and dry weight. There was no significant difference in cobs per plant, stem, leave and total dry weight as well as cob fresh and dry weight and number of leaves at harvest expect grains per plot. Difference in performance was observed in cob fresh and dry weight where 50 % CEWD performed better than

100 %, 75 % and 25 % CEWD. 75 % CEWD had the highest leaves area index at the reproductive stage also recorded higher grains filling.

Cob per plant ranges from 1.2 to 1.4 with no significant differences across the treatments. The effect of water stress on flowering dates (days to tasselling and silking) were shown in the Table 4.2. There was no significant difference in flowering dates which relate to the level of stress undergo by sweet corn.

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TABLE III: Effect of water stress regimes on growth and yield parameters at harvest

	GROWTH									YIELD			
CEWD	DAS TO 50%T	DAS TO 100%T	DAS TO 50%S	DAS TO 100%S	Dry wgt of leaves	Stem dry wgt	Tassel dry wgt	Total dry wgt	No. of leaves	Cob/plt	Grains/plt	Cob fresh wgt	Cob dry wgt
					Kgha^{-1}						Kgha^{-1}		
25%	59	73	66	78	271.0	851.0	35.6	1157.0	10	1.3	121.0c	2387.0	819.0
50%	56	67	64	75	201.0	502.0	30.4	733.0	9	1.2	207.0b	3184.0	1634.0
75%	55	66	63	71	273.0	710.0	38.4	1021.0	13	1.2	288.0a	2760.0	1484.0
100%	55	67	65	73	400.0	981.0	71.0	1453.0	10	1.4	212.0b	2546.0	1046.0
lsd (p<0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	73.2	NS	NS
CV%	2.5	8.3	12.1	6.5	19.3	18.9	20.1	19.4	7.8	17.6	7.2	7.8	14.0

CEWD – crop-environmental water demand; DAS – Days after sowing; wgt – Weight; plt – Plant; No – Number

T – Tasselling

S – Silking

NS – Not significant

DISCUSSIONS

Water application rates per treatment per plot (Irrigation procedure) and pre-planting physical and chemical properties were presented in Tables I and II respectively reflect the pre-planting and post-planting activities on the experimental field. Watering can be used to apply the volume of water to each of the plot. Measuring bowl was however used to arrive at the accurate volume of water applied thus maintain adequate soil moisture for plant growth. The nutrient status of the field indicated by the pre-planting chemical analysis was medium. The total nitrogen, available phosphorus and organic carbon are all in the medium range require for plant growth while the level of potassium is low according to Federal Fertilizer Department of Nigeria (2001). The pH of the soil was slightly acidic (6.1) and the class was loamy sand (USDA) indicated that the soil was desirable for sweet corn developments according to Schultheis (2010). Saturated hydraulic conductivity as well as permeability and total porosity indicated the soil as a well drain and aerated also key indicator for soil moisture availability. However, fertilizer was applied (see materials and method) to satisfied high nutrients demanded of the sweet corn.

Randomization of the treatments imposed was presented in Fig, 1. This was to ensure Genetic by Environment relationship (G x E) and to reduce experimental error. Effects of water stress regimes on plant growth (4.2) were also presented in Fig. 4.2, 4.3, 4.4,4.5, 4.6 and 4.7. The statistical analyses of the results show that there was no significant difference across the treatment imposed at the early stage (14 and 28 days after sowing) of the sweet corn growth. Thereafter, significant difference was observed in the treatments imposed on leaf area index; plant height and shoot dry weight while number of leaves was not significantly different across the treatments throughout the experiment period. Leaf area index of the treatments imposed reflected the ability of the sweet com to actively utilized solar energy in photo synthetic process. The performance was higher in 100 % and 75 % CBWD treatments than in 50 % and 25 %. The same trend was observed in plant height where the mean average plant height was in relation to water application rates as well as in shoot dry weight of the sweet corn. However, the

leaves area index, plant height and shoot dry weight performance across the treatments reflects the source and sink stage. The results also indicated that shoot dry weight increases with increase in soil moisture level. At this stage that is source and sink, sweet corn requires more resource to satisfy its morphological and reproductive development than what was required to off-set the evapo-transpiration demand of the atmosphere. Therefore, the sweet corn growth performance was in order of 100 % > 75 % > 50 % > 25 % CEWD. Again, the stage indicates source and sink which signal the commencement and termination of both reproductive and vegetative phase in plant.

At harvest, growth and yield was considered which was presented in table 4.3. There was no significant difference in number of cobs per plant, cob fresh and dry weight but significant difference was observed in number of grains per plant, the grain yield was in order of 75 % > 100 % > 50 % > 25 %, the same as in the sweet growth before harvest. This could be as a result of higher photosynthetic activities observed in sweetcorn growth which was related to water application rates.

The growth parameters considered at harvest were number of leaves, stem dry weight, total dry weight, tassel dry weight, days to tasselling and silking, Significant difference was not observed in all the growth parameters considered at harvest. The trend observed was the same as that of the sweet corn growth before harvest.

CONCLUSION

Water application rates influenced tassel and silk phase of the sweet corn with 75% CEWD attain reproductive stage similar to TOO % CEWD, Sweet corn number of grain per plant were in order 75 % > 100 % > 50 % > 25 % CEWD. Therefore, application of 75 % CEWD significantly influenced tasselling and silking resulting to higher grain yield than other treatment imposed.

In all, 75 % CEWD significantly improved growth and yield of sweet corn on loamy sand soil on sustainable basis.

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