Assessment of the Behaviour of Growth Responses of C3 and C4 Crops to Climate and Soil Physico-Chemical Parameters in Rivers State, Nigeria

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Abstract: - This study assessed the behaviour of growth responses of C3 and C4 crops to climate and soil physico-chemical parameters in Rivers State, Nigeria. The C3 crops refer to Pumpkin and Cucumber while C4 crops refer to Amaranthus in this study. The research work made use of three crops (Pumpkin, Cucumber and Amaranthus in some selected sites in Rivers State and the study was carried out both in the dry and wet seasons. Soil samples were collected from both topsoil (0-15cm) and subsoil (15-30cm). The experiment was observed for 43rd, 49th, 56th, 63rd, and 70th day of planting. The crops and soil samples were taken to the laboratory for further analysis. The crops and soil samples were taken to the laboratory for further analysis. Mean values and standard deviations were used to describe the analysis while analysis of variance (ANOVA), Duncan, and Kruskal Wallis were used to test the hypotheses. All analyses were carried out using Statistical Package for Social Sciences (SPSS) 21.1 Version. Findings showed that evapotranspiration, temperature and carbon dioxide were significantly varied during wet and dry seasons across the three locations. However, in the 43rd period for Amaranthus and evapotranspiration, leaf and protein were significant; during the 49th period in pumpkin and evapotranspiration, height, leaf, energy, water and phosphorus were significant. In the 43rd period for Cucumber and temperature, height, leaf, energy, water and carbohydrates were significant. Finally, in the 70th period, for Pumpkin and Temperature, Vitamin A, water, height, protein and energy were significant at $p<0.05$. For the physico-chemical properties of soil, it was found that in terms of sand content, Oyigbo had the highest in the topsoil at 95.37% while Etche had highest in silt content at 1.87%. For the Subsoil, Oyigbo also had the highest sand content at 93.30% while Ikwerre had the highest clay content at 6.63% in subsoil. For chemical properties of soil, Total Organic Carbon and Magnesium were highest in Oyigbo at 1.91% and 24.00% respectively for topsoil while for subsoil potassium was highest in Ikwerre at 8.30%. For standards recommended by (USDA 2014) only energy, iron, zinc, riboflavin, pyridoxine and pantothenic acid at Oyigbo met the standards, also Riboflavin and iron at Ikwerre met the (USDA 2014) standards while only folates at Etche met the (USDA 2014) Standards. The study recommended that the soil nutrients and pH should be improved across the three locations and the acidic nature of both topsoil and subsoil should be improved by neutralizing the soil with lime.

Key Words: — ***Evapotranspiration, Temperature, Carbon dioxide, C3, C4.***

I. INTRODUCTION

1.1 Background

Globally, climate change as earlier identified by Inter-Governmental Panel on Climate Change (IPCC, 1987) in Montreal Protocol in Canada, has been defined as the change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. These changes are caused by certain gases such as: carbon dioxide, water vapor, and temperature rising. These three elements have contributed in altering the physiological pattern of some plants and thereby creating pathological effects on them arising from anthropogenic

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activities Mabel (2011). Temperature rise on these plants as a result of increase in CO_2 concentration has not been fully ascertained on how plants responds to these plants during their growth stages. Kubien (2015) has called for thorough study on plants' responses to temperature variation because of its role in nutrient reduction. The point raised above is that temperature and CO_2 contribute to the physiological patterns of C3 crops during their growth stage but there is need to determine in scientific terms and experimentation using both C3 and C4 crops to identify these features and what climatic variable plays such role.

Evapotranspiration which is the combined loss of water from both the plants and the soil to the atmosphere has contributed to the high envelop or saturation of the atmosphere and at the same time drought to the soil and dryness to the plants. Evapotranspiration affects soil moisture condition and crop water requirement (Liang, Li and Liu, 2010; Behmanesh, Rezaverdinejad and Mehdizadeh, 2014). Aside this, transpiration in plants cannot be overemphasized because of its link to climate variation.

Plants also cool the atmosphere directly through the process known as transpiration, when the temperature increases and the surrounding atmosphere heats up, plants must find a suitable way to release its excess water into the air from their leaves and this invariably cools the surrounding environment but when there is excess transpiration, what happens to the crops?, that is why Dinpashoh (2006) has stated that accurate prediction of a crop evapotranspiration (ETc) has an essential role in agricultural water management . This prediction according to Dinpashoh (2006) must recognize the plants distinctiveness, its peculiarities and the environment in which it was planted and how it affects plants. This study is aimed at providing this needed information through our experimentation.

Plants Evapotranspiration was found to be more sensitive towards climatic variables such as relative humidity, temperature, wind speed, sunshine hours and other parameters (Jayaram, Thippeswami, Rajashekar, Raj and Gowda, 2018). This sensitivity may decrease on different scale index due to alteration in climatic variables including evapotranspiration. Evapotranspiration was found to be more important and integral component of hydrological cycle, which has significant and direct impact on hydrological aspects and a link with temperature and transpiration which is one of the variables to be considered during this work. (Jayaram et al, 2018). Rising concentration of carbon dioxide (CO_2) in the atmosphere, increase in temperature and evapotranspiration variations are amongst major factors determining changes and development in most plants (Marco, 2012).

These conditions could negatively impact crops especially C3 crops (these are plants most efficient during photosynthesis such as: cowpea, beans, rice, wheat, potatoes, pumpkin, and cucumber) yields and C4 plants such as maize, Amaranth, sugarcane, sorghum and other vegetables in many parts of the world including Nigeria. Excess or less CO_2 variations can create many physiological and climatic effects on plants which generally has its impact on man after consumption and his environment. The responses of plants' species but in this case amaranth, pumpkin and Cucumber to factors of climate variations such as temperature, water vapour, elevated (CO_2), evapotranspiration and land use, was comprehensively reviewed by Sage and Kubien (2003) who explained that this cannot be separated as instruments that alter man's environment. Such alteration and effects are: reduction in sugar and nutrient contents of plants, susceptibility for less development in the leaf, changes in stomata conductance, vegetative growth effect, plant's variations in locations etc. These are major concerns of this study because some of the variations in climatic conditions like temperature, carbon dioxide and evapotranspiration contribute in reducing the physiological conditions of these plants but the representation of this facts varies from one researcher to another thereby projecting the result in a different view, like that of assertions between Allen (1990) and Morison (1985) which maintains that plants' stomata conductance occurs when there is an increase in carbon dioxide which allows the guard cell to open more for large transpiration responses and at the same time plays a key role in climate variation, and in modern time Sleen (2015) counters such claims and states that such does not occur even with an elevated carbon dioxide.

This claim and counter claim makes it paramount to also determine the role of increased carbon dioxide on temperature which also affects the level of transpiration in plants. Most of these issues arise because of the inability to scientifically use a combination of C3 or C4 plants in proving this fact rather most studies chose a single direction of species such as C3 crops was adopted and used for generalization.

There is a need to delve into this area because of its role in human life, there is a high limited research information on CO_2

variations and its effects on transpiration and vegetative growth making growth abnormality in crops a subject of discuss across the globe and this is why this study is centered on the growth response of amaranth, pumpkin and cucumber to variations in evapotranspiration, temperature and CO_2 concentration especially in selected sites in Rivers State.

Temperature has become a determining factor during plants growth but little has been examined to determine its effect on plants development and physiological changes. In several areas, there is an increase in temperature while in other areas; there is a less increase in temperature. But this variation has created in some plants the loss of sugar content, loss of nutrients, loss of essential vitamins and other varieties which have been on increase in plants and this has also been attributed to virus during plants growth but with less emphasis on temperature variation impacts during plants growth and development.

Again, growth rate of plants is dependent on transpiration level and how these plants respond to different temperatures heating on them. The volume of evapotranspiration in most cases is high in midday and less in morning, the less water in a plant, less effective such plant is therefore, excess transpiration in crops could have created a deficit in those crops during their growth stages and this is the anchor of this study to determine how plants responds to this variation of evapotranspiration in the environment.

II. Materials And Methods

The study area is Etche , Ikwerre and Oyigbo Local Government aresa of Rivers State in the Niger Delta Region of Nigeria. It is located in the southern region, and has been reported to be one of the major biodiversity hotspots in the world (Izah et al., 2017a; Izah and Seiyaboh, 2018). The ecosystem is home to several Crops such as Cucumber, Pumpkin and Amaranthus potentials. The three Local governments contain coal plain terrace soil that are recommended by the FAO (2011) for C3 and C4 crops. The prominent season for these locations is dry and wet seasons. The wet seasons starts from March to November while the dry seasons starts from November ending to February. The temperature (28 ±8 ºC) and relative humidity (50 - 95%) is within the estimated range of the area (Izah et al., 2017b). Primary data were generated during the field data gathering using Atmometer for land level, GPS for location, CO_2 detector for carbon dioxide (Carbon assimilates), thermometer for temperature reading and Evaporimeter for transpiration and evaporation reading. Carbon assimilates, temperature reading and evapotranspiration reading where measured in periods like the 43rd period, 49th periods, 56th period, 63rd period and 70th periods in both dry and wet seasons .

The research design adopted in this work has a treatment combination in Randomized Complete Block Design (RCBD) in factorial Experiment.

Factors to be considered:

- Factor A (Main Factor): Amaranth, Pumpkin and Cucumber = Crop.
- Factor B (sub-factor i) Evapotranspiration, Temperature and Carbon dioxide=Environment.
- Factor C (sub-factor ii) Ambient and Variation= Condition
- Factor D (sub-factor iii) Etche, Oyigbo and Ikwerre = Location

NB: Each treatment combination was replicated 3times. This implies that treatment combination = A x B x C x D x Rep (3x3x2x3x3) = 162.

Schematic Presentation of Treatment Combination

This segment explains the schematic treatment combination where the first Factor A (crop) is multiplied with the second first Sub-factor B (Environment) for example: Amaranthus combined with Evapotranspirtaion that gives AmEp.

Table.1. Schematic Presentation of Treatment Combination

AxB	Amaranth (Ok)	Pumpkin (Pu)	Cucumber (Cc)
Evapotranspiration (Ep)	AmEp	PuEp	CcEp
Temperature (Tp)	AmTp	PuTp	CcTp
Carbon dioxide (Co)	AmCo	PuCo	CcCo

This segment deals with the treatment combination with the three factors: factor A (Crop) combined with Sub-factor B (Environment) and with sub-factor C (Season). For example: Factor A (crop), sub-factor B (Environment) and sub-factor C (Season)

Table.2. AB x C

ABxC	AmEp	AmTp	AmCo	PuEp	PuTp	PuCo	CcEp	CcTp	CcCo
Ambient (S1)	AmEpS1	AmTpS1	AmCoS1	PuEpS1	PuTpS1	PuCoS1	CcEpS1	CcTpS1	CcCoS1
Chamber (S2)	AmEpS2	AmTpS2	AmCoS2	PuEpS2	PuTpS2	PuCoS2	CcEpS2	CcTpS2	CcCoS2

Table 2 also explains the combination of the four factors: the crop, environment, season and the locations.

Table.3. ABC x D

Ikwerre (Ik)	Oyigbo (OY)	Etche (ETC)
AmEpS1Ik	AmEpS1 OY	AmEpS1ETC
AmTpS1Ik	AmTpS1 OY	AmTpS1ETC
AmCoS1Ik	AmCoS1 OY	AmCoS1ETC
PuEpS1Ik	PuEpS1 OY	PuEpS1ETC
PuTpS1Ik	PuTpS1 OY	PuTpS1ETC
PuCoS1Ik	PuCoS1 OY	PuCoS1ETC
CcEpS1Ik	CcEpS1 OY	CcEpS1ETC
CcTpS1Ik	CcTpS1 OY	CcTpS1ETC
CcCoS1Ik	CcCoS1 OY	CcCoS1ETC
AmEpS2Ik	AmEpS2 OY	AmEpS2ETC
AmTpS2Ik	AmTpS2 OY	AmTpS2ETC
AmCoS2Ik	AmCoS2 OY	AmCoS2ETC
PuEpS2Ik	PuEpS2 OY	PuEpS2ETC
PuTpS2Ik	PuTpS2 OY	PuTpS2ETC
PuCoS2Ik	PuCoS2 OY	PuCoS2ETC
CcEpS2Ik	CcEpS2 OY	CcEpS2ETC
CcTpS2Ik	CcTpS2 OY	CcTpS2ETC
CcCoS2Ik	CcCoS2 OY	CcCoS2ETC

1. Data that was taken include but not limited to:

2. Agronomic data such as plant height, leaf number, 50% days flowering, maturity and total yield etc.

3. The soil sample was taken from the surface down to 15cm, which is from 0-15 cm, and from 15cm to 30cm, it was also sent for laboratory test and the result is stated in chapter four. We took the soil temperature of the three plants starting from 0-2cm depth. This is because in planting amaranth and pumpkin, 2cm is recommended while that of cucumber 3 cm FAO (2011).

4. Land equivalent ratio to plant was also calculated, we have 5 by 5 for cucumber and pumpkin crops per bird and a total of 9 birds in a location. This gives each bird a 25.

5. Geo-ecological data such as: evapotranspiration rates, carbon assimilates, temperature reading, physico-chemical properties, relative humidity data and day length were also taken for the various locations studied etc.

6. All data were subjected to analysis in a RCBD in factorial experiment where interactions were tested for AxB; AxC,AxD,BxC,BxD,DxC, DxB others were on ABxC,ABxD,ACx D and ABCxD , they were subjected to ANOVA and Duncan analysis with error mean square.

III. RESULTS AND DISCUSSIONS

This session analyses the three climatic parameters (Evapotranspiration, Temperature and Carbon Dioxide) with C3 and C4 crops. It shows the mean value, standard deviation, minimum and maximum values, lower bound values and the total number selected in the study.

Table.4. Descriptive Statistics analysis of CO_2, Temperature and Evapotranspiration, Relative Humidity during the Wet Season

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean: Lower Bound	95% Confidence Interval for Mean: Upper Bound	Minimum	Maximum
CO2	Amaranthus	90	888.6996	61.22259	6.45343	875.8767	901.5224	725.00	999.00
	Cucumber	90	896.4780	61.21604	6.45274	883.6565	909.2995	738.00	998.00
	Pumpkin	90	897.0441	55.82066	5.88401	885.3527	908.7355	711.99	987.00
	Total	270	894.0739	59.37538	3.61347	886.9596	901.1882	711.99	999.00
Temp	Amaranthus	90	33.1164	5.48598	.57827	31.9674	34.2655	24.80	45.00
	Cucumber	90	32.9461	5.24146	.55250	31.8483	34.0439	24.09	41.80
	Pumpkin	90	33.0828	4.92963	.51963	32.0503	34.1153	24.80	41.90
	Total	270	33.0484	5.20505	.31677	32.4248	33.6721	24.09	45.00
Ev	Amaranthus	90	10.3588	4.32665	.45607	9.4526	11.2650	1.10	17.20
	Cucumber	90	10.2640	3.84152	.40493	9.4594	11.0686	1.10	17.40
	Pumpkin	90	9.7714	4.27979	.45113	8.8751	10.6678	1.10	24.10
	Total	270	10.1314	4.14762	.25242	9.6344	10.6284	1.10	24.10
RH	Amaranthus	90	36.7296	30.77323	3.24378	30.2842	43.1749	3.00	99.72
	Cucumber	90	46.5953	105.30214	11.09982	24.5402	68.6504	4.00	990.40
	Pumpkin	90	36.2711	30.10845	3.17371	29.9650	42.5772	6.30	99.91
	Total	270	39.8653	65.61028	3.99291	32.0040	47.7267	3.00	990.40
a. grow season = Wet									

Table 5 below shows significant responses of these three crops to Evapotranspiration variations. The N represents the total number selected.

Evapotranspiration analysis with three crops using Duncan Statistical tools in SPSS 21.1

Table.5. Statistical representation of Evapotranspiration and the three crops using

Crop grown	N	Subset for alpha = 0.05
		1
Pumpkin	90	9.0222
Amaranthus	90	9.3189
Cucumber	90	9.5414
Sig.		.04
Means for groups in homogeneous subsets are displayed.		
a. grow season = Dry/Wet		
b. Uses Harmonic Mean Sample Size =90.000.		

Table 6 below shows significant responses of these three crops to Temperature variations. The N represents the total number selected.

Table.6. Testing the temperature and the three crops using Duncan during drys

			Season.
Crop grown	N	Subset for alpha = 0.05	Grow season
		1	Dry
Cucumber	90	35.9371	Dry Season
Pumpkin	90	36.0454	
Amaranthus	90	36.0456	
Sig.		.04	
Means for groups in homogeneous subsets are displayed.			
a. grow season = Dry; b. Uses Harmonic Mean Sample Size = 90.000.			

The table 7 below shows significant responses of these three crops to CO_2 variations. The N represents the total number selected.

Table.7. Testing of CO_2 and the three crops during dry season using the Duncan

Crop grown	N	Subset for alpha = 0.05	Grow Season
		1	Dry
Amaranthus	90	916.4453	
Pumpkin	90	921.2806	Dry Season
Cucumber	90	922.0493	
Sig.		.03	
Means for groups in homogeneous subsets are displayed.			
a. grow season = Dry			
b. Uses Harmonic Mean Sample Size = 90.000.			

Statistical responses of Amaranthus, Pumpkin and Cucumber to Variations in Evapotranspiration, Temperature and Carbon dioxide in relation to Minerals and Nutrients

The table 8 shows the different responses of C3 and C4 crops to variations in Carbon Dioxide, Temperature and Evapotranspiration in crops. The study made use of the Duncan Statistical tool in SPP21.1 for analysis. The P/O in the table represents the period of observation to the field, these periods are the periods of visitations.

The table only highlighted nutrients and minerals that were significant at various observations. The height, leaf, energy, protein, water, Dietary fiber, Cholestrol, Vitamin A, phosphorus and calcium were significant at the the 43^{rd} , 49^{th} , 56^{th}, 63^{rd} and 70^{th} periods.

Table.8. Statistical responses of Amaranthus, Pumpkin and Cucumber to Variations in Evapotranspiration, Temperature and Carbon dioxide in relation to Minerals and Nutrients

Minerals/ Nutrients	Crop	Climatic parameter	Statistical tool	Duncan/Corr Value	N	Sig(2tailed)	P/O
Height	Pumpkin	Temperature	Duncan/SPSS 21.1	.224	36	.005	70th
Leaf	Pumpkin	Temperature	Duncan/SPSS 21.1	.036	36	.04	70th
EnergyKcal	Pumpkin	Temperature	Duncan/SPSS 21.1	.160	36	.005	49th
Protein	Amaranthus	Evapotranspiration	Duncan/SPSS 21.1	.157	36	.03	43rd
Water	Cucumber	Evapotranspiration	Duncan/SPSS 21.1	.064	36	.04	49th
Phosporous	Amaranthus	Evapotranspiration	Duncan/SPSS 21.1	.842	36	.014	49th
D/Fiber	Pumpkin	Evapotranspiration	Duncan/SPSS 21.1	.063	36	.017	56th
Calcium	Pumpkin	Evapotranspiration	Duncan/SPSS 21.1	.632	36	.041	56th
Leaf	Amaranthus	Evapotranspiration	Duncan/SPSS 21.1	.823	36	.03	63rd
Vitamin A	Cucumber	Carbon Dioxide	Duncan/SPSS 21.1	.0652	36	.028	70th
Cholesterol	Amaranthus	Carbon Dioxide	Duncan/SPSS 21.1	.0873	36	.044	49th

IV. Conclusions

This study evaluated the growth responses of C3 and C4 crops to Climatic Parameters and Soil Physio-Chemical Properties in Rivers State. C3 crops in this study refer to Cucumber and Pumpkin while the C4 crop refers to Amaranthus. The climatic parameters in this study refer to Evapotranspiration, Temperature and Carbon dioxide and emphasis was on their variations to these C3 and C4 crops. Methodologically, three locations where selected in Rivers State namely: Etche, Oyigbo and Ikwerre this is because the three locations have the coal plain terrace soil as recommended by FAO (2011) in planting Cucumber , Pumpkin and Amaranthus. Agronomic such as plant height, leaf number, 50% days flowering, maturity, total yields and geo-ecological data such as: evapotranspiration rates, carbon assimilates, temperature reading were collected. The study made use of Randomized Complete Block Design in factorial experiment. From the discussions of findings, it was Revealed Pumpkin, Cucumber and Amaranthus responded to evapotranspiration, temperature and carbon dioxide variations at the 43rd, 49th, 56th, 63rd and 70th periods of observations in the field. This variation in climatic parameters also affected the crops Nutrients and mineral such as : Vitamin A, Energy, Phosphorous, Protein, Height, Leaf, D/Fiber, and Cholesterol.

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