

**EFFECTS OF CLIMATE CHANGE CRITICAL FACTORS ON THE
SEEDLING GROWTH AND DEVELOPMENT OF MAIZE (*Zea mays L.*)**

**EDEMA, N.E.
DEPARTMENT OF BOTANY
DELTA STATE UNIVERSITY
P.M.B. 1, ABRAKA
E-mail: drangeledema@yahoo.com
Phone No. 08028530761**

Abstract

Crop production is highly dependent on weather and change in climate has a major effect on crop yield, and thus on food supply. The effect of critical factors for climate change on growth and development of *Zea mays* was investigated. The treatments used were water, temperature, light intensity and soil (pH and nutrients). Growth factors such as height, leaf area, fresh and dry weights as well as dry and fresh weight ratio were determined. An average weight of 3kg of sandy, clay, loamy and laterite (red) soils in black planting bags of 21 by 25cm were used. Single (SN) and double (DN) netted cages were constructed to reduce the amount of light absorbed by plants. The control was without net (WN) while another set without net₁ (WN₁) was subjected to drought (watered only once). Three replicates for each soil treatment were used, and the experiment lasted for 8 Weeks. The results revealed that seeds sown in clay and laterite soils for WN₁ germinated and died after three weeks because of the drought condition. Loamy soil for SN showed the highest mean height of 125cm $\pm$ 0.95. Also, loamy soil (WN) had the highest values of 214.49cm² $\pm$ 0.35 and 92.90g $\pm$ 3.21 for leaf area and dry weight, respectively. Soil pH values for sandy and loamy soils were within the acceptable pH range of 6.5 – 8.5. Plants sown in loamy soil for SN, DN and WN flowered within the period of the experiment. The highest value of 1.80g weight for inflorescence was recorded for WN with loamy soil. For loamy soil, there was significant difference between all soil treatments (nutrient, temperature and light intensity) at P<0.05. Since salts (ions) absorption is through solution in the soil, water may be considered as the most critical factor for the growth and development of plants.

Keywords: Growth, light intensity, nutrients, soil pH, temperature, water, *Zea mays*.

Introduction

Maize (*Zea mays*) belongs to the family *Poaceae* (grass family). It is widely grown because it is adapted to different ecological conditions and it is more extensively distributed over the earth than other cereal crops (Remison, 2005). It is mostly grown in regions with a temperature range of 21 – 30°C. It is not suitable to humid sub-tropics climate. It does well in sandy, loamy soils rich in nutrients, especially nitrogen. The time of flowering is influenced by photoperiod and temperature. It is considered a short-day plant, when flowering is hastened and vegetative growth retarded by long night. Long days increase the leaf number, plant size and length of the growing period. *Zea mays* is grown in Nigeria, several zones from coastal swamps of the South to the dry savanna lands of the North (Remison, 2004).

Maize is a major grain crop grown worldwide. It is regarded as one of the world's major food crops feeding humanity since ages. It also serves a major ingredient for feeding animals in poultry, swine and cattle ranches. In addition to its use as human and animal food, it is also a potential crop for ethanol.

As industrial raw materials, corn starch, oil, syrup and sugar are the chief industrial products obtained from maize. Other uses include the use of stalks and leaves for making paper board and wall board (Remison, 2005).

Nature provides a large portion of the environmental influence on maize growth and yields, however, the maize producer can manipulate the environment with managerial operations including hybrid selection, soil tillage, soil fertilization, irrigation, crop rotation and pest control to achieve his aims.

Climate change is a long-term change in the elements of climate, such as temperature, precipitation, humidity, wind, sunlight and pressure, threshold over a long period of time of at least several decades. The term climate change is also used synonymously with 'global warming' (Daintith and Martin, 2005). Critical climatic factors like temperature, sunlight and rainfall have direct effect on plant environment, crop yield and thus food supply. **Precipitation and temperature are the dominant factors governing crop growth.**

Temperature exerts a major effect on crop growth rate; plant development and growth can be retarded when the temperature is either too low or too high (Monteith, 2006). Important direct effects of climate on crops will be through changes in temperature, precipitation, length of growing season and timing of extreme or critical threshold events, relative to crop development (Saarikko and Carter, 1996). Climate change also will modify rainfall, evaporation, run-off and soil moisture storage.

The temperature range that supports plant growth is generally from 4.5 – 36⁰C, Optimum temperature for growth varies with the species and stages of

development; and usually fluctuates between night and day. Several growth processes are sensitive to temperature. Among these are respiration, flowering, fruit ripening and dormancy (Noggle and Fritz, 1976).

Plants respond to light of wavelength from 300 to 800nm. Plants grown in the absence of light are said to be etiolated. Etiolated plants lack chlorophyll; they are tall and spindle-shaped with long internodes. They also have small leaves that have failed to expand (Hopkins and Hunner, 2004). Light accelerated many phases of growth while inhibiting certain aspects of internodes elongation. Light can have an effect on the morphology of plants. Leaves of the same plant may differ depending on whether they are sun leaves or shade leaves. Sun leaves are often thicker with extra layers of palisade parenchyma and shorter petioles

The response of plant to light varies depending on the intensity, duration and wavelength of light it received. Light intensity refers to the concentration of light waves striking a leaf surface. Light plays a critical role in plant growth and development. The quantity, quality and direction of light are perceived by photosensory systems which collectively regulate plant development presumably to maintain photosynthetic efficiency (Hangarter, 1997).

Photo-oxidation damage, that is, light dependant generation of reactive oxygen species (ROS) in chloroplast, is a key process involved in cell damage and death in plants exposed to environment stress factors (Okunlola and Adelusì,

2012). The response of plants to stress conditions differs among cultivars, within species, and among stages of plant development with cultivar (Okunlola and Adelusi, 2012). The response reflects differences in area of adaptation and in the biological mechanisms that have evolved for coping with adverse environmental conditions. Light indirectly affects the transpiration and photosynthesis by showing its influence on salt absorption.

Seeds require water, air (oxygen) and proper temperature range such that biochemical processes can operate. A seed is considered germinated when it has produced a plant that is potentially capable of continuous growth. Water is one of the raw materials required for photosynthesis and production of new compounds. A net loss of water will cause growth to stop and continued deficiency results to death (Noggle and Fritz, 1976). A growing plant absorbs water from the soil and gives it off in transpiration. Transpiration loss of water in exchange for carbon (IV) oxide is necessary for plant growth. However, water stress caused a reduction in height, leaf area, root biomass, whole plant biomass, leaf area ratio and relative growth rate of stress plants (Umebese *et al.*, 2012).

Plant growth and development are influenced by physical, chemical and biological components in plants environment. Any factor that is less or more than optimum, i.e. deficient or in excess, will limit plant growth (Hopkins and Hunner, 2004). Phosphorus uptake is influenced by temperature and a deficiency may be

induced by cool nutrient solution temperature. The pH of soil can also affect the availability of nutrient to plants. One of the reasons behind giving importance to soil pH is that the occurrences of some of the diseases are dependent on the pH of the soil. Gardening with improper level of soil pH can result in poor yield of crops. The decrease in pH of soil solution accelerates the absorption of anions while the increase in pH favours the absorption of cations. The pH values across the physiological range may inhibit salt absorption (Verma and Verma, 2007)

Climate change factors do not work separately/singling, but interact and modify the environment. The effects of these interactions on life forms in general and the growth of maize in particular is critical. This study is aimed at simulating climate change critical factors on the growth and interpreted for future climate change alternatives.

Materials and Methods

The composite maize seed variety (yellow type) was used for this study. It was purchased from Obiaruku Local Market, Obiaruku, Ukwani Local Government Area of Delta State, Nigeria. Before used, the seeds were soaked in water for ten minutes (10 minutes) to test for viability. Forty-eight black planting bags measuring 21 x 25cm were purchased from Lagos Street around King Square in Benin-City, Edo State. Cages (2) were constructed with height of 5ft and breath

of 2ft. The first cage was constructed with a single mosquito net and a chicken net (Single net, SN) and the second cage was constructed with a double mosquito and chicken nets (DN), they were constructed to reduce the amount of light and temperature available to the plants. The duration of the experiment was from the 4th of December, 2010 to 4th of February, 2011. Sandy, clay, loamy and laterite soils were used. The reason was to determine the effect of the different soil levels (in terms of nutrient status) on the growth of plant (*Zea mays*).

The experiment was set up at the Department of Botany, Delta State University, Abraka, Nigeria. The experiment was laid out in a split-split plot design with three replicates per soil. Between row spacing was 0.75 and within row spacing was 0.25m. Three seeds were sown to a depth of 2cm per bag containing 3kg of the different soils. Six rows were also planted outside (natural condition) with three (3) replicates of each soil. The single double, without net (WN) experiment were watered once a day, while the without net₁ (WN₁) was watered only once (subjected to drought) throughout the experiment. The WN₁ was introduced to mimic a very dry environment. Rainfall was not recorded in Abraka, Delta State, South-South, Nigeria throughout the duration of the experiment. The experiment was terminated on the 14th February, 2011 (when the first rain for the year was experienced).

Elemental Soil analysis

One gram of soil sample from each of the treatment groups was placed in a teflon beaker followed by the addition of 9ml HNO_3 (60% v/v), 4ml of HF (40% v/v), 2ml of perchloric acid (70% v/v) and 1ml of HCL (37% v/v). The digestion mixture was heated to 120°C in regulated digestion block in the fume chamber. The completely mineralized sample was dissolved using 5ml of 1 M HNO_3 solution, and filtered with Whatman (No. 1) filter paper and diluted to 25ml mark with 1 M HNO_3 . The solution was subsequently analyzed for N, P and K using flame emission spectrum photometric method (Perkin –Elmer, 1968).

Physical analysis:

The pH values were measured using pH meter. The values for light intensity were measured using light meter (digital lux meter-model-LX1010B). Temperature was measured with a simple thermometer.

Plant Analysis:

Leaf area analysis was by Remison (1997). That is length x the widest width x 0.75. Weighing balance (Electronic Balance HZ-K-600Eb) and digital weighing balance (Model-OHAUS) were used for fresh and dry weights respectively. The plants were measured with the help of a tape. While, the ratio of fresh to dry weight was done by dividing the mean dry weight by fresh weight.

Statistical analysis

The data were subjected to two-way ANOVA with replications using mean $\pm$ standard error, Two-way analysis of variance.

Results and Discussion

Effects of climate change critical factors on the seedling growth and development of maize (*Zea mays*) were investigated. Best growth conditions for *Zea mays* were average daytime temperature, 36.35°C (Table 2); light intensity, 499.75x10²Lux/m² (Table 2); pH, 7.02 (Table 7) and loamy soil (WN). At these conditions there were absorptions of P and K (Table 1) and increased fresh and dry weights (highest = 92.72g $\pm$ 3.20 (Table 4) and 396.60g $\pm$ 5.77 (Table 3), respectively). Phosphorus is a constituent of ATP, nucleic acids, phospholipids and

certain coenzymes. It is very important in plant energy transfer and deficiency can slow down growth considerably. While potassium acts as a coenzyme or activator of many enzyme systems. High potassium levels are required for protein synthesis and fruit production in most crop (e.g. tomato) as the demand for potassium in fruit is high (Jackson *et al*, 2000). Active cell division, elongation and development processes promote absorption of salt (Verma and Verma, 2007). The absorption of ions is influenced by the presence of other ions in the medium e.g the absorption of potassium is found to be affected by the presence of calcium, magnesium and other cations in the external medium (Verma and Verma, 2007)

Laterite and clay soils WN₁ exposed to drought condition (water stress) had no growth (Table 3,4,5). When plants are exposed to increasing stress, they tend to have reduced total dry matter and leaf number. Water is one of the raw materials required for photosynthesis and production of new compounds, a net loss of water will cause growth to stop and continued deficiency will result in death (Noggle and Fritz, 1976). During environmental stress such as drought, reactive oxygen species (ROS) which include oxygen, ions, free radicals and peroxides increases dramatically resulting in oxidative damage to protein and lipid (Apel and Hirt, 2004).

The different treatments for loamy soil show significant difference between all other soil treatments (nutrient, temperature and light intensity) at $p < 0.05$.

There were decreases in P ion in the soil after exposure e.g. DN and SN treatments (Table 1), this may be attributed to the critical factors, that affected the growth of the maize plants, and consequently, the fruiting and yield of the plants. Loamy soil without net (WN) had the highest weight of 1.80g (Table 9). It also revealed that light and temperature contributed to the production of inflorescence. At optimal temperature of 36.35 ± 0.28 and light intensity of $499.75 \times 100 \text{ Lux/m}^2 \pm 2.20$ (Table 2) as recorded above. This supports the report of Noggle Fritz, 1976 and Remison, 2005, that several growth processes like flowering, respiration, fruit ripening and dormancy are sensitive to temperature.

At $35.40^\circ\text{C} \pm 0.42$ temperature and $214.91 \times 10^2 \text{ Lux/m}^2 \pm 175.70$ light intensity (Table 2) the development of plant height and leaf area increased ($125.00 \pm 9.03\text{cm}$, Table 5 and $214.99\text{cm}^2 \pm 0.35$ (Table 8) respectively) in loamy soil. While the highest values of dry and fresh weights were recorded for loamy soil with WN. The lowest values for leaf area (Table 8), fresh weight (Table 3), dry weight (Table 4), and plant height (Table 5) were recorded for WN₁ (Clay and laterite, followed by sandy and loamy) soils. This shows that water or precipitation, and nutrient are very critical for the growth and development of plants. Plants grown in the absence of light are said to be etiolated. Etiolated plants lack chlorophyll, they are tall and spindle-shaped with long internodes. They also have small leaves that have failed to expand (Hopkins and Hunner, 2004). It also shows

that pH values of loamy soil before and after are within the optimum pH. Soil with improper level of pH can result in poor yield of crop plants.

The absence of water inhibits the absorption of nutrients by plants. For most part of the year when there is no water the nutrients adhere to and accumulate in the soil till when water is available. This may account for the high protein in annual grasses that grow in the fertile soil of the Sahel most part of the year. Maize plants in the savanna were taller with higher ear placement, suggesting greater vigor of growth. Percentage moisture content at harvest was consistently lower at the savanna than at forest location in hybrid variety. This implies a shorter grain in filling duration and/or a faster dry-down rate in the savanna than in the forest ecologies (Hopkins, 1999). Climate change modifies soil moisture by creating environmental stress such as drought and flooding. When this happens salt (ions) absorption by plants will be affected. When nutrients are lacking the yield of crops may become affected. Since salts (ions) absorption is through soil solution, water may be considered as the most critical factor for the growth and development of plants.

Conclusion

The results revealed that seeds sown in clay and laterite soil for WN₁ germinated and died after three weeks. This shows that precipitation is the main factor responsible for the death of the plants. Climate change modifies soil moisture by creating environmental stress such as drought. The absence of water inhibits the absorption of nutrient by plants. When this happens salt (ions) absorption by plants may be affected. This may also account for the very low values recorded for fresh wt, dry wt, leaf area and height of plants in WN₁

The result also showed reduction in values of K in SN, WN (Table 1) in loamy soil after exposure. It indicates that potassium was absorbed by the plants. Potassium levels are required for the protein synthesis and fruit production in most crops as the demand for potassium by developing fruit is high. Changes in temperature and precipitation (climate change factors) delayed maturation/flowering of *Zea mays* by altering the nutrient status of the soils.

REFERENCES

Apel, K. and Hirt, H.(2004). Reactive oxygen species: *Annual Review of Plant Biology*. 55:373-399

Daintith, J. and Martin E. (2005). *Oxford dictionary of science*. 5th ed. Oxford University Press. 170-171

Hangarter, (1997). Gravity, light and plant forms . *Plant, Cell and Environment*. 20:796 – 800

Hopkins, W.G. and Hunner, N.P.L.(2004) *Introduction to plant physiology*. 4th edition, John Wiley and Sons Incorporation. London. Pp 25-29

Hopkins, W.G. (1999) *Introduction to plant physiology*. 2nd ed. John Wiley and Sons Incorporation. London. 512

Jackson, M.B. (2000). Aeration in the nutrient film technique of glasshouse crop production and the importance of oxygen, ethylene and carbon dioxide. *Acta Hort*. 98:61-78

Monteith, J.L. (2006). Climate variation and growth of crops. *Meteorol. Soc*. 107:749 - 774

Noggle, G.R. and Fritz, G.J.(1976). *Introductory plants physiology*. Prentice Hall,

Inc. New Jersey.

Okunlola G.O. and Adelusi, A.A.(2012). Effects of nutrient and light stress on the morphological parameter of tomato [*Licopersicum esculentus mill*]. *Ife Journal of Science*. 14:289-296

Perkin-Elmer, C. (1968). An analytical method for atomic absorption spectrometry. In: *Selected methods for soil and plant analysis*. IITA, Ibadan, Nigeria

Remison, S.U.(2005). Arable and vegetative crops of the tropics. Gift Prints Associates, Benin-City, Nigeria. Pp 4-18.

Remison, S.U.(2004). Agriculture as the way. Ambik Press. Benin-City, Nigeria. 73p

Remison, S.U.(1997). Basic principles of crop physiology, Sadoh, Benin-City. 163

Saarikko, R.A. and Carter, T.R.(1996). Estimating regional spring wheat development and suitability in Finland under climate warming. *Climate. Res*. 7:243-252.

Umebese, C.E., Okunade, K.I. and Orotupe, O.M.(2012). Impact of water deficient stress on growth and alkaloid content of organs of *Spigelia anthemia* (L). *Ife Journal of Science*. 14:357-362.

Verma, S.K. and Verma, M.(2007). A textbook of plant physiology, biochemistry

and biotechnology. Sixth edition, S. Chand and Company Ltd. New Delhi. Pp
118-123.

APPENDIX:

Table 1: Macronutrients (NPK) of soil

	P				N				K			
Treatment	Sandy	Clay	Loamy	Laterite	Sandy	Clay	Loamy	Laterite	Sandy	Clay	Loamy	Laterite
Before Exposure (Control)	20.25 ± 0.96	18.43 ± 0.38	18.89± 0.47	18.74± 0.40	0.15± 0.03	0.37± 0.07	0.22± 0.06	0.20± 0.04	0.75± 0.23	0.94± 0.26	1.22± 0.06	1.00±0.00
After exposure												
(SN)	19.22± 0.88	19.42± 0.67	18.68± 0.35	19.42± 0.68	0.15± 0.03	0.24± 0.03	0.16± 0.04	0.10± 0.03	1.11± 0.00	1.23± 0.06	1.20± 0.06	0.81±0.23
(DN)	20.55± 0.28	20.74± 0.54	20.37± 0.28	19.79± 0.28	0.28± 0.09	0.23± 0.01	0.10± 9.81	0.14± 0.04	0.70± 0.15	0.86± 0.24	1.15± 0.03	1.00±0.05
(WN)	19.72± 0.26	20.25± 0.96	18.55± 3.77	18.31± 0.51	0.30± 0.30	0.32± 0.06	0.41± 0.21	0.25± 0.03	1.17± 0.06	1.21± 0.06	1.06± 0.03	0.77±0.25
(WN ₁)	18.95± 0.18	18.31± 0.58	18.46± 2.14	18.86± 0.25	0.21± 0.06	0.26± 0.04	0.27± 0.09	0.17± 0.03	1.16± 0.66	0.78± 0.33	1.32± 0.01	1.11±0.01

Table 2: Average light and daytime temperature at 8 weeks

Treatment	Temp °C	Light Lux/m ²)
SN	35.49 ± 0.42	214.94 x 100 ± 175.07
DN	33.50 ± 0.74	149.95 x 100 ± 95.44
WN	36.35 ± 0.28	499.75 x 100 ± 28.20
WN ₁	38.75 ± 0.21	499.23 x 100 ± 351.8

Table 3: Mean fresh wt_(g) of plants at week 8

Treatment		Sandy	Clay	Loamy	Laterite
SN	14.20±1.95	1.55±0.12	374.86±4.02	5.90±2.67	
DN	6.90±3.40	2.50±0.30	129.29±13.56	5.40±2.47	
WN	8.00±2.08	4.40±0.85	396.60±5.77	4.86±1.69	
WN1	1.30±0.1	0.00±0.00	91.60±2.37	0.00±0.00	

Table 4: Mean dry wt_(g) of the plant at week 8

Treatment	Sandy	Clay	Loamy	Laterite
SN	3.40±0.35	0.40±0.06	63.00±7.84	2.20±0.19
DN	3.20±0.67	0.80±0.50	31.40±6.53	1.60±0.82
WN	3.30±0.61	2.50±0.47	92.70±3.20	3.00±0.36
WN ₁	0.30±0.12	0.00±0.00	22.40±1.52	0.00±0.00

Table 5: Mean height (cm) of maize seedlings at week 8

Treatment	Sandy	Clay	Loamy	Laterite
SN	49.00±32.19	28.67±2.91	125.00±9.03	40.40±9.84
DN	56.33±9.01	34.70±10.06	116.43±26.76	45.40±12.65
WN	40.10±5.77	29.47±2.39	106.10±6.98	55.70±15.70
WN ₁	23.40±3.30	0.00±0.00	78.17±7.57	0.00±0.00

Table VI: Ratio of fresh wt to dry wt_(g)

Treatment	Sandy	Clay	Loamy	Laterite
SN	4.18±0.05	3.88±0.06	5.92±7.84	2.68±0.19
DN	2.16±0.67	3.13±0.50	4.17±6.53	3.38±0.82
WN	2.42±0.61	1.76±0.47	4.28±3.21	1.62±0.75
WN ₁	4.33±0.12	0.00±0.00	4.09±1.52	0.00±0.00

Table VII: Mean pH values of the soil

Treatment	Sandy	Clay	Loamy	Laterite
Before exposure (control)	6.21±0.41	5.54±3.84	7.30±3.00	5.70±3.65
SN	6.53±3.86	4.69±3.18	6.84±3.07	3.10±0.52
DN	6.98±3.33	3.92±3.17	6.83±3.31	4.33±3.05
WN	6.72±3.30	4.53±3.35	7.02±3.00	4.14±2.98
WN ₁	6.81±3.35	5.20±3.00	8.06±3.48	5.88±3.32

Table 8: Mean leaf area at week 8

Treatment	Sandy	Clay	Loamy	Laterite
SN	43.17±0.03	12.42±0.02	214.49±0.35	22.06±0.25
DN	52.19±0.18	18.43±0.36	183.31±6.81	26.11±7.15
WN	34.99±4.02	14.32±0.91	171.87±3.42	22.93±1.28
WN ₁	4.89 ±	0.00±0.00	106.80±0.06	0.00±0.00

Table 9: Weight of fresh flowers (g)

Cage	Sandy	Clay	Loamy	Laterite
SN	0.00 ± 0.00	0.00 ± 0.00	1.30±0.06	0.00 ± 0.00
DN	0.00 ± 0.00	0.00 ± 0.00	0.30±0.01	0.00 ± 0.00
WN	0.00 ± 0.00	0.00 ± 0.00	1.80±0.44	0.00 ± 0.00
WN ₁	0.00 ± 0.00	0.00 ± 0.00	0.00±0.00	0.00 ± 0.00

