

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

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 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 ± 0.95. Also, loamy soil (WN) had the highest values of 214.49cm² ± 0.35 and 92.90g ± 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

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 causes of climate change include the external processes of variation of solar emissions, variations of the earth's orbit, volcanic eruptions, mountain building and tectonic movements, anthropogenic (human induced) processes include the increase of greenhouse gases as a result of activities that include the burning of fossil fuels, changes in land use, and the emission of aerosols. Internal processes, natural interactions within the climate system, are also factors. 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. The over-riding climatic factor is temperature, and it is by this that the world is divided into its major climatic zones of which the tropic is one. However, within the tropics rainfall is the most important climatic factor.

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

55 extreme or critical threshold events, relative to crop development (Saarikko and
56 Carter, 1996). Climate change also will modify rainfall, evaporation, run-off and
57 soil moisture storage.

58 Temperature range that supports plant growth is generally from 4.5 – 36⁰C,
59 Optimum temperature for growth varies with the species and stages of
60 development; and usually fluctuates between night and day. Several growth
61 processes are sensitive to temperature. Among these are respiration, flowering,
62 fruit ripening and dormancy (Noggle and Fritz, 1976).

63 Plants respond to light of wavelength from 300 to 800nm. Plants grown in
64 the absence of light are said to be etiolated. Etiolated plants lack chlorophyll; they
65 are tall and spindle-shaped with long internodes. They also have small leaves that
66 have failed to expand (Hopkins, 2004). Light accelerated many phases of growth
67 while inhibiting certain aspects of internodes elongation. Light can have an effect
68 on the morphology of plants. Leaves of the same plant may differ depending on
69 whether they are sun leaves or shade leaves. Sun leaves are often thicker with extra
70 layers of palisade parenchyma and shorter petioles (Kerr et al., 2005).

71 Response of plant to light varies depending on the intensity, duration and
72 wavelength of light it received. Light intensity refers to the concentration of light
73 waves striking a leaf surface. Light plays a critical role in plant growth and
74 development. The quantity, quality and direction of light are perceived by

75 photosensory systems which collectively regulate plant development presumably
76 to maintain photosynthetic efficiency (Hangarter, 1997).

77 Photo-oxidation damage, that is, light dependant generation of reactive
78 oxygen species (ROS) in chloroplast, is a key process involved in cell damage and
79 cell death in plants exposed to environment stress factors (Okunlola et al., 2012).
80 The response of plants to stress conditions differs among development with
81 cultivars, within species, and among stages of plant development with cultivar
82 (Okunlola et al., 2012). The response reflects differences in area of adaptation and
83 in the biological mechanisms that have evolved for coping with adverse
84 environmental conditions. Light indirectly affects the transpiration and
85 photosynthesis by showing its influence on salt absorption.

86 Seeds require water, air (oxygen) and proper temperature range such that
87 biochemical processes can operate. A seed is considered germinated when it has
88 produced a plant that is potentially capable of continuous growth. Water is one of
89 the raw materials required for photosynthesis and production of new compounds.
90 A net loss of water will cause growth to stop and continued deficiency results to
91 death (Noggle and Fritz, 1976). A growing plant absorbs water from the soil and
92 gives it off in transpiration. Transpiration loss of water in exchange for carbon (IV)
93 oxide is necessary for plant growth. However, water stress caused a reduction in

94 height, leaf area, root biomass, whole plant biomass, leaf area ratio and relative
95 growth rate of stress plants (Umebese et al., 2012).

96 Plant growth and development are influenced by physical, chemical and
97 biological components in plants environment. Any factor that is less or more than
98 optimum, i.e. deficient or in excess, will limit plant growth (Hopkins, 2004).
99 Phosphorus uptake is influenced by temperature and a deficiency may be induced
100 by cool nutrient solution temperature. The pH of soil can also affect the availability
101 of nutrient to plants. One of the reasons behind giving importance to soil pH is that
102 the occurrences of some of the diseases are dependent on the pH of the soil.
103 Gardening with improper level of soil pH can result in poor yield of crops. The
104 decrease in pH of soil solution accelerates the absorption of anions while the
105 increase in pH favours the absorption of cations. The pH values across the
106 physiological range may inhibit salt absorption (Verma and Verma, 2007)

107  Maize (*Zea mays*) belongs to the family *Poaceae* (grass family). It is widely
108 grown because it is adapted to different ecological conditions and it is more
109 extensively distributed over the earth than other cereal crops (Remison, 2005). It is
110 mostly grown in regions with a temperature range of 21 – 30°C. It is not suitable to
111 humid sub-tropics climate. It does well in sandy, loamy soils rich in nutrients,
112 especially nitrogen. The time of flowering is influenced by photoperiod and
113 temperature. It is considered a short-day plant, when flowering is hastened and

114 vegetative growth retarded by long night. Long days increase the leaf number,
115 plant size and length of the growing period. *Zea mays* are grown in Nigeria, several
116 zones from coastal swamps of the South to the dry savanna lands of the North
117 (Remison, 2004).

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

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

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

129 The three most ecological important environmental factors affecting plant
130 growth are temperature, water and light. Therefore, there is need to investigate the
131 effect of these critical factors for climate change on the growth and development of
132 plants generally and *Zea mays* in particular.

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Materials and Methods

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The *Zea mays* seeds used for this study were 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 nets and chicken net (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 0.25m. Three seeds were sown to a depth of 2cm per bag containing 3kg of the different soils. Four rows were also planted outside with three (3) replicates of each soil. The

153 single double, without net (WN) experiment were watered once a day, while the
 154 without net₁ (WN₁) was watered only once (subjected to drought) throughout the
 155 experiment. The WN₁ was introduced to mimic a very dry environment. Rainfall
 156  was not recorded in Abraka, Delta State, South-South, Nigeria throughout the
 157 duration of the experiment. The experiment was terminated on the 14th February,
 158 2011 (when the first rain for the year was experienced).

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160 Elemental Soil analysis

161 One gram of soil sample from each of the treatment groups was placed in 
 162 teflon beaker followed by the addition of 9ml HNO₃ (60% v/v), 4ml of HF (40%
 163 v/v), 2ml of perchloric and (70% v/v) and 1ml of HCL (37% v/v). The digestion
 164 mixture was heated to 120°C in regulated digestion block in the fume chamber.
 165 The completely mineralized sample was dissolved using 5ml of 1 MNN0₃ solution,
 166 and filtered with Whatman (No. 1) filter paper and diluted to 25ml mark with 1
 167 MHN0₃. The solution was subsequently analyzed for N, P and K using flame
 168 emission spectrum photometric method.

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171 Physical analysis:

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

175 Plant Analysis:

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

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182 Statistical analysis

183 The data were subjected to two-way ANOVA with replications using mean $\pm$
184 standard error, Two-way analysis of variance and comparison test (Bonferroni 

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Results and Discussion

189 Effects of climate change critical factors on the seedling growth and
 190 development of maize (*Zea mays*) were investigated. Best growth conditions for
 191 *Zea mays* were temperature 36.35° light intensity, 499.75x10²Lux/m²; pH, 7.02
 192 and loamy soil (WN). At these conditions there were absorptions of P and K, and
 193 increased dry and fresh weights (highest = 92.72g±3.20 and 396.60g±5.77,
 194 respectively) as shown in Tables 1 II, III and IV. Active cell division, elongation
 195 and development processes promote absorption of salt (Verma and Verma, 2007).
 196 The absorption of ions is influenced by the presence of other ions in the medium
 197 e.g the absorption of potassium is found to be affected by the presence of calcium,
 198 magnesium and other cations in the external medium (Verma and Verma, 2007)

199 Laterite and clay soils WN₁ exposed to drought condition (water stress) had
 200 no growth. When plants are exposed to increasing stress, they tend to have reduced
 201 total dry matter and leaf number. Water is one of the raw materials required for
 202 photosynthesis and production of new compounds, a net loss of water will cause
 203 growth to stop and continued deficiency will result in death (Noggle and Fritz,
 204 2003). During environmental stress such as drought, reactive oxygen species
 205 (ROS) which include oxygen, ions, free radicals and peroxides increases

dramatically resulting in oxidative damage to protein and lipid (Appel and Hert, 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 was depletion of ions from the plants arising from the effects of these critical factors, thereby affecting 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. This supports the report of Noggle Fritz, 1996 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 the development of plant height and leaf area increased ($125.00 \pm 9.03\text{cm}$ and $214.99\text{cm}^2 \pm 0.35$ respectively) in loamy soil. While dry and fresh weights were recorded for loamy soil with WN_1 . The lowest values for leaf area, fresh weight, dry weight, and plant height were recorded for WN (Clay and laterite) 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 lack chlorophyll they are tall and spindle-shaped with long internodes. They also have small leaves that have failed to expand (Hopkins, 2004). It also

225 shows that pH values of loamy soil before and after are within the optimum pH.

226 Soil with improper level of pH can result in poor yield of crop plants.

227 The absence of water inhibits the absorption of nutrients by plants. For most
228 part of the year when there is no water the nutrients adhere to and accumulate in
229 the soil till when water is available. This may account for the high protein in
230 annual grasses that grow in the fertile soil of the Sahel most part of the year.
231 Climate change modifies soil moisture by creating environmental stress such as
232 drought and flooding. When this happens salt (ions) absorption by plants will be
233 affected. When nutrients are lacking the yield of crops may become affected.
234 Since salts (ions) absorption is through soil solution, water may be considered as
235 the most critical factor for the growth and development of plants.

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237 **Conclusion**

238 In conclusion, maize can be properly cultivated in a dry environment and
239 during the dry season only if water and nutrients are made available to the plants as
240 soil solution 

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REFERENCES

Adejare, F.B. and Umebese, C.E.(2008). Water stress induces cultivar dependent changes in samatal complex, yield and osmotic adjustment in *Glycine max* L. International Journal of Agricultural Research. 3: 287-295.

Apel, K. and Hart, H.(2004). Reactive Oxygen Species: Annual Review of Plant Biology. 55:373-399

Byerlee, D. and Eicher, C.K. (1997). Africa's emerging maize revolution. Lynne Rienner Publishers, 301p

Chenge, M. and Johnson, D.(1994). State of the environment in Southern Africa. African Research and Documentation Centre. Vol. 322p

Crossley, M.N., Dennison, W.C., Williams, R.R. and Wearing, A.H. (2002). The interaction of water flow and nutrients on aquatic plant growth. Hydrobiology. 489: 6370

- 262 Food and Agricultural Organization of the United Nations. (2001). Towards
263 2015/2030 summary report.
264
- 265 Hangeter, (1997). Gravity, light and plant forms . Plant, Cell and Environment. 20:
266 796 – 800
267
- 268 Hopkins, W.G. and Hunner, N.P.L.(2004) Introduction to plant physiology. 4th
269 edition, John Wiley and Sons Incorporation. London. Pp 25-29
270
- 271 IPCC.(2008). Second assessments report of climate change. In: Houghton, J.I.
272 Maris Fillo, I.G., Callender, B.A., Kattenburg, N., Maskell K. (ends). The
273 Science of Climate Change. Cambridge University Press. U.K.
274
- 275 Monteith, J.L. (2006). Climate variation and growth of crops. Meteorol. Soc.
276 107:749 - 774
277
- 278 Noggle, G.R. and Fritz, G.J.(1976). Introductory plants physiology. Prentice Hall,
279 Inc. New Jersey.
280
281

282 Okunlola G.O. and Adelusi, A.A.(2012). Effects of nutrient and light stress on the
283 morphological parameter of tomato [*Licopersicum esculentus mill*]. Ife
284 Journal of science.

285

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

288

289 Remison, S.U.(2004). Agriculture as the way. Ambik Press. Benin-City, Nigeria.
290 73p

291

292

293 Saarikko, R.A. and Carter, T.R.(1996). Estimating regional spring wheat
294 development and suitability in Finland under climate warming. Climate. Res.
295 7:243-252.

296

297 United States Department of Agriculture.(2010) Foreign Agricultural Service.
298 Production, supply and distribution online. Custom query. Available and
299 accessed. 17 May, 2010.

300

301

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

305

306 Verma, S.K. and Verma, M.(2007). A textbook of plant physiology, biochemistry
307 and biotechnology. Sixth edition, s. Chand and Company Ltd. New Delhi. Pp
308 118-123.

309

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APPENDIX:

Table 1: Macronutrients (NPK) of soil

	P				N				K			
	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
												
(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  Average light and temperature at 8 weeks

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

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

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

	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)

	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
WN1	4.33±0.12	0.00±0.00	4.09±1.52	0.00±0.00

Table VII: Mean pH values of the soil

	Sandy	Clay	Loamy	Laterite
Before exposure	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 VIII: Mean leaf area at week 8

	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

