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# Assessing the impact of climate change on the growth and yield of tomato (*Lycopersicon esculentum*) cultivars in Obudu, northern Cross river state, Nigeria

LAWRENCE AHMED UGBE [1,*], PETER UNDIUKEYE USHIE [1], AKINMOLA SOLOMON MOREBISE [2] and FELIX ANGIOSHUYE AKOMAYE [3]

[1] *Department of Agricultural Education, Federal College of Education Obudu in Affiliation with The University of Calabar, Nigeria.*
[2] *Department of Crop Production, Santa Cruz State University, Ilhéus, Bahia, Brazil.*
[3] *Department of Agricultural Education, Faculty of Education, University of Calabar, Nigeria.*

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## Abstract

This research work was carried out to assess the impact of climate change on the growth and yield of tomato varieties cultivated separately in a Greenhouse and in an open field. The design of the experiment was a Randomized Complete Block (CRB) with split plot arrangement. Tomato nurseries of four cultivars (Ibadan Local, Roma, Rotina and Santa Cruz) were prepared separately in the open field and in a Greenhouse. The nursery seedlings in the open field were transplanted after 4 weeks at nursery to prepared beds, while the nurseries in the Greenhouse were transplanted also after 4 weeks at nursery to wooden boxes filled with fertile loamy soil, arranged in 4 rows of 5 per row in a Greenhouse. Each row represented a subplot and there were 4 blocks in the entire plot. The experiment was replicated 3 times. The tomato cultivars were the subplots while the cultivation environments (open field and Greenhouse) were the main plots. All cultural activities were applied in the subplots except in control plots for both open field and Greenhouse. Growth data such as Leaf Area Index, stem girth, and plant height per stand were recorded at 2 weeks after transplanting, while yield data such as number of days to flowering, number of fruits per stand, fruit weight in kg/ha and fruit yield in t/ha were also recorded at 9 and 12 weeks after transplanting. All data generated were subjected to analysis of variance (ANOVA) procedure for split plot experiment using GENSTAT statistical software version 8.1 means were separated using Least Significant Difference (LSD) at 5% level of probability. It was recommended that farmers should tune their agricultural practices to incorporating a more sustainable climate smart agriculture. While in cultivating tomato, emphases should be on using high yielding cultivars such as Santa Cruz, and Rotina. Extension agents should be trained on climate smart agriculture so that they can in turn assist farmers in adopting the system for mitigating climate change effect.

**Keywords:** Climate Change; Climate Smart; Greenhouse; Controlled Environment; Significant Difference

## 1. Introduction

Evidence is gathering that human activities are responsible for the changing climate. According to the magazine [1] this change could have impact on human lives as the earth is getting warmer and warmer every day. The climate has been thrown completely out of kilter as each day comes with fresh proof such as more frequent and more violent cyclones in the Caribbean, floods in Africa, the gradual sinking of Islands, heat waves in Europe and the melting of glaciers [2]. Global temperatures have risen by 0.74oC in the last 30 year [2]. This global rise in temperatures has led to huge impact on a wide range of climate related factors such as a continuous rise in the levels of carbon dioxide, methane and nitrous oxide

* Corresponding author: LAWRENCE AHMED UGBE

gases, mainly as a result of human activities [3]. Carbon dioxide is continuously dumped in the atmosphere at an alarming rate.

According to the Inter-governmental Panel on Climate Change (IPCC) climate change is a change in the state of climate that can be identified.For instance, by using statistical test. This can be identified by changes in the mean and or the variability in the climates' properties, which is capable of persisting for as long as decades. The American Meteorological Society (AMS) defined climate change as any systematic change in the longer-term statistics of climate element which include temperature, pressure or winds. The society added that such system change is sustained over several decade or even longer. Climate change may be due to natural external forces, such as changes in solar radiations or slow changes in the earth's orbital elements. These include the natural internal processes of the climate system or anthropogenic forces [4].

[5] observed that climate change refers to changes that are attributed directly or indirectly to human activities that alter the atmospheric composition of the earth thereby leading to global warming. This is collaborated by [6] that climate change is a normal part of the earth's natural variability, which is related to interactions among the atmosphere, ocean, and land, as well as changes in the amount of solar radiation reaching the earth.

### 1.1. Effect of climate on agriculture

Climate change effect on agriculture is already great, especially in the dry tropical regions which are already fragile due to population pressure. Unlike in the temperate regions, tropical Africa experiences shorter growing seasons when the temperature rises due to climate change phenomenon [6]. When this happens, grains such as rice start declining in yield with temperatures over $34^0$ C [2]. There is a theory of carbon fertilization: which says that higher levels of $CO_2$ in the atmosphere will enhance photosynthesis in many key crops and in turn boost their yields. According to [1] carbon fertilization is a mirage. Not only does the initial acceleration in growth, slows down significantly after a few days or weeks, but also the increase in $CO_2$ reduces nitrogen and protein levels in the leaves of crops by more than 12 %. This therefore means that with climate change, there will be less protein in major cereals like rice and wheat for human consumption. This also means less protein in leaves for bugs, so bugs will eat more of leaves, leading to severe reductions in yield [1].

Climate change is not only causing a change in the weather patterns in many regions, but also natural disasters such as drought, floods and tropical storms are increasing in frequency and intensity. In 2007 alone, parts of Africa suffered severe drought, while floods on much of the continent destroyed roads, and buildings and wipe out millions of hectares of farm land [2]. Also in March 2008, Cyclone Ivan struck Madagascar destroying crops, livestock and buildings [1]. Persistent drought in Swaziland has forced some communities out of their homes. Outside Africa, the Caribbean has been hit by a succession of extreme weather events, causing millions of Dollar worth of damage. For instance, in Papua New Guinea (PNG), Cyclone Guba caused flash floods in late 2007, burying crops under mud slide [2].

The UK Hadley Centre for Climate Change observed that temperature increase in parts of Africa could be double the global average increase. According to the centre, with Africa's heavy dependence on agriculture, its high proportion of low-inputs, rain fed farming (95 %) and existing stresses such as land degradation and population pressure, the impact of climate change here may be greatest. An increase of 5 to 8 % of arid and semi-arid land in Africa is projected under a range of climate change scenario [6]. [7] reported that some climate changes occur abruptly, while others will involve gradual shift in temperature, vegetation cover and fish stocks. Secondary stresses triggered by climate change are likely to include the spread of pests and alien species, biodiversity losses and the increase in human and animal disease.

In Nigeria, sometimes the rains come late in the year and disappear early in the same year, thereby affecting planting seasons in the country. The length of the rainy season and the rainfall intensity have drastically reduced [4]. However, since these factors have a direct impact on crops, the falling outputs in areas where communities rely almost exclusively on agriculture have a devastating effect. Erosion intensity is increasingly washing away useful fertile top soils in different parts of the country, especially in the southern part [8]. Flood in the country has become a recurrent decimal, ravaging different parts of the country. Climate Change is already putting great pressure on agriculture in Nigeria.

Tomato as a crop, can be grown in wide range of climates. It does better in moderate, evenly distributed rainfall, with much sunshine. A warm day temperature of $10\text{-}20^0$ C and deep fertile, free draining soils with $P^H$ range of 5.5-7.5 are ideal for tomato production [9]

### 1.2. Statement of the problem

Obudu in northern part of Cross River State which experiences both tropical rain forest Climate and the Guinea Savanah climate in different parts, is beginning to witness remarkable Climate Change effect. The Climate Change has started changing the dynamics of drought, rainfall and waves in this region. Secondary stress factors such as the spread of pests and diseases of crops are on the increase, with competition for resources and attendant loss of biodiversity. Agriculture is generally affected as crop yields are declining with rainfall becoming unpredictable, drought and desertification are gradually setting in unprecedentedly to eliminate the forests and the green vegetations. On the whole, agricultural production is worse hit.

Therefore, it is becoming imperative to conduct different research works on climate change including its effect on the growth and yield of individual crops. Results of such research works will be made public and will guide farmers in decision making towards mitigating the effect of climate change on crop production.

*Objective of research*

The overall objective of the research work is to determine the degree of effect of Climate Change on crop production in the study area. The specific objectives include.

- To determine the effect of Climate Change on the growth of tomato
- To determine the effect of Climate Change on the yield of tomato
- To encourage climate smart agriculture among farmers in the study area and beyond.

## 2. Materials and methods

This work was carried out at the teaching and research farm of Federal College of Education Obudu, in northern Cross River State. Obudu is bounded by Obanliku Local government Area to the East, down to the southern part, Bekwarra Local government Area to the West and Vandeikya Local Government Area of Benue State to the North. Obudu has two vegetation zones, the tropical rain forest in the interior parts close to eastern Boki, and the Guinea Savannah zone along the boundary with Benue State. Obudu experiences a bimodal annual rainfall distribution in the range of 2,500-3000 mm with a main annual temperature range of $27^{o}$ C to $35^{o}$ C and a Relative humidity of about 80-85% [10].

The design of the experiment was a Randomized Complete Block (CRB) with split plot arrangement. Tomato nursery of four (4) cultivars (Ibadan local, Roma, Rotina, and Santa Cruz) were prepared on beds in the open field and in boxes kept in Green House. Wooden boxes of size (50 x 50 x 50) cm were filled with good fertile soil and arranged five (5) in a row. There were four (4) raws in each block each row represented a subplot, and flour blocks in the entire plot, giving 80 boxes in the entire plot. The layout was replicated three times and tomato seedlings of the four cultivars were transplanted after four weeks in nursery. Three stands were planted per box giving a plant population of 240 in a replicate and 720 stands in the three replicates in a Green House.

A nearby field was cleared and mounds constructed 20 in each block and 80 in the entire plot, according to the design of the experiment. It was replicated three times and tomato of the four selected cultivars were planted at 50 x 90 cm on the mounds in order to also get a population of 720 stands in the entire experimental field. All cultural activities were carried out both in the field and in the green house. Temperature, humidity, sunshine and moisture levels were regulated in the Greenhouse; while in the open field, they were left unregulated. The tomato cultivars were the subplot while the cultivation environment was the main plot.

Growth data were taken as leaf area index ($cm^2$) stem girth ($cm^2$) and plant height (cm) per stand, at 2 weeks after transplanting. Yield data considered were number of days to flowering, number of fruits per stand, fruit weight in kg/ha and fruit yield in tons per hectare (t/ha). All yield readings were taken at between 9 and 12 weeks after planting (9 and 12 WAP).

All data generated were subjected to analysis of variance (ANOVA) procedure for split plot experiment, using GENSTAT statistical software version 8. Means were separated using Least Significant Difference (LSD) at 5% level of probability.

## 3. Results

**Table 1** Effect of Climate Change on the growth of tomato varieties cultivated in an uncontrolled environment (open field)

| **Treatments** | | | | |
|---|---|---|---|---|
| **varieties** | **Cultural Practices** | **Leaf Area index ($cm^2$)** | **Stem girth ($cm^2$)** | **Plant height per stand (cm)** |
| Ibadan land | Control | 15.20 | 2.50 | 60.00 |
| | Weed control | 12.60 | 2.20 | 60.21 |
| | Fertilizer pest | 12.50 | 2.22 | 60.25 |
| | Pest control | 14.20 | 3.00 | 62.20 |
| | Mulching | 15.00 | 3.20 | 65.22 |
| | Staking | 15.21 | 2.52 | 66.32 |
| | SED | 7.83 | 12.25 | 14.36 |
| | LSD | 2.06 | 0.96 | 3.26 |
| Roma | Control | 14.22 | 2.50 | 60.25 |
| | weed control | 14.25 | 3.00 | 66.22 |
| | fertilizer | 13.26 | 3.21 | 63.25 |
| | pest control | 13.22 | 2.22 | 62.32 |
| | mulching | 14.30 | 2.25 | 65.10 |
| | staking | 15.10 | 3.36 | 62.00 |
| | SED | 6.38 | 5.26 | 15.62 |
| | LSD | 2.53 | NS | 1.21 |
| Rotina | Control | 15.23 | 3.22 | 58.20 |
| | Weed control | 14.26 | 3.41 | 56.43 |
| | Fertilizer | 14.22 | 2.82 | 65.32 |
| | Pest control | 14.32 | 2.61 | 60.22 |
| | Mulching | 15.00 | 2.66 | 62.36 |
| | Staking | 14.24 | 2.52 | 60.42 |
| | SED | 12.34 | 0.96 | 7.64 |
| | LSD | NS | 1.22 | 2.06 |
| Santa Cruz | Control | 14.26 | 3.24 | 65.33 |
| | Weed control | 14.31 | 3.61 | 60.28 |
| | Fertilizer | 15.22 | 2.74 | 56.42 |
| | Pest control | 15.42 | 3.32 | 60.32 |
| | Mulching | 14.22 | 2.83 | 63.41 |
| | Staking | 13.43 | 3.26 | 70.10 |
| | SED | 10.62 | 5.66 | 8.43 |
| | LSD | 2.31 | 1.26 | 2.32 |

Table 1 above shows that the leaf area index, the steam girth and plant height per stand of varieties I and 4 (Ibadan local and Santa Cruz respectively) were significantly different ($p<0.05$) in terms of cultivation in an uncontrolled environment (Open field). However, the stem girth in variety 2 (Roma) was not significantly different ($p>0.05$) while the leaf area index was not significantly different ($p>0.05$) in variety 3 (Rotina) (Table 1).

**Table 2** Effect of Climate Change on the growth of tomato varieties cultivated in a controlled environment (Green House)

| **Treatments** | | | | |
|---|---|---|---|---|
| **Varieties** | **Cultural practices** | **Leaf Area index ($cm^2$)** | **Stem girth ($cm^2$)** | **Plant height per stand (cm)** |
| Ibadan local | Control | 15.22 | 2.60 | 50.10 |
| | Weed control | 13.00 | 3.22 | 65.22 |
| | Fertilizer | 12.40 | 3.62 | 66.62 |
| | Pest contact | 13.62 | 3.56 | 68.52 |
| | Mulching | 14.21 | 3.46 | 67.86 |
| | Watering | 14.62 | 3.41 | 70.22 |
| | SED | 9.21 | 0.30 | 0.34 |
| | LSD | NS | 0.81 | 0.95 |
| Roma | Control | 14.34 | 2.62 | 45.26 |
| | Weed control | 15.22 | 3.42 | 50.38 |
| | Fertilizer | 14.82 | 3.33 | 60.25 |
| | Pest control | 14.76 | 2.86 | 60.32 |
| | Mulching | 15.36 | 3.46 | 58.62 |
| | Watering | 15.28 | 2.78 | 650.32 |
| | SED | 0.34 | 0.32 | 8.01 |
| | LSD | NS | 0.71 | 1.2 |
| Rotina | Control | 13.63 | 2.88 | 50.22 |
| | Weed control | 14.22 | 3.62 | 65.38 |
| | Fertilizer | 14.82 | 3.52 | 64.41 |
| | Pest control | 15.61 | 3.63 | 63.82 |
| | Mulching | 15.52 | 3.26 | 62.76 |
| | Watering | 15.63 | 3.43 | 66.35 |
| | SED | 7.33 | 0.52 | 0.82 |
| | LSD | 15.39 | NS | 27.2 |
| Santa Cruz | Control | 14.22 | 2.46 | 52.43 |
| | Weed control | 15.63 | 3.51 | 55.66 |
| | Fertilizer | 15.42 | 3.48 | 58.28 |
| | Pest control | 14.83 | 3.36 | 60.34 |
| | Mulching | 14.78 | 3.38 | 60.62 |
| | Watering | 15.36 | 3.52 | 58.43 |
| | SED | 16.14 | 0.86 | 11.55 |
| | LSD | 33.55 | 1.76 | 23.99 |

Analysis of Table 2 above shows that the leaf area index, the stem girth per stand and the plant height per stand, were significantly different ($p<0.05$) in variety 4 (Santa Cruz). The leaf area index was not significantly different ($p>0.05$) in varieties 1 and 2 (Ibadan local and Roma respectively). While the stem girth per stand was not significantly different ($p>0.05$) in variety 3 (Rotina), all in cultivation under controlled environment (Greenhouse).

**Table 3** Effect of Climate Change on the yield in tons per hectare (t/ha) of tomato varieties cultivated in an uncontrolled environment (Open field)

| **Treatments** | | | | | |
|---|---|---|---|---|---|
| **Varieties** | **Cultural practices** | **No of days to flowering** | **No of fruits/stand** | **Fruit weight in kg** | **Fruit yield in t/ha** |
| Ibadan local | Control | 38.31 | 20.32 | 10.52 | 12.21 |
| | Weed control | 36.34 | 25.22 | 15.21 | 12.42 |
| | Fertilizer | 38.22 | 20.66 | 15.22 | 13.31 |
| | Pest control | 37.31 | 19.52 | 15.62 | 12.22 |
| | Mulching | 38.40 | 18.62 | 15.32 | 12.36 |
| | Staking | 37.62 | 20.21 | 14.31 | 12.16 |
| | SED | 12.32 | 10.24 | 12.64 | 14.41 |
| | LSD | 0.86 | NS | NS | 0.94 |
| Roma | Control | 37.82 | 21.41 | 10.11 | 10.22 |
| | Weed control | 36.33 | 23.14 | 12.21 | 14.32 |
| | Fertilizer | 38.21 | 18.44 | 11.52 | 13.26 |
| | Pest control | 37.31 | 19.21 | 13.22 | 14.22 |
| | Mulching | 38.32 | 20.11 | 12.11 | 15.21 |
| | Staking | 37.52 | 22.12 | 12.22 | 14.31 |
| | SED | 10.24 | 12.22 | 10.26 | 13.64 |
| | LSD | 1.23 | NS | NS | 0.92 |
| Rotina | Control | 38.10 | 30.209 | 10.22 | 12.25 |
| | Weed control | 38.13 | 28.56 | 12.31 | 14.44 |
| | Fertilizer | 37.24 | 30.22 | 13.22 | 14.38 |
| | Pest control | 37.16 | 27.65 | 15.62 | 15.25 |
| | Mulching | 37.22 | 28.32 | 14.52 | 14.29 |
| | Staking | 38.18 | 29.23 | 15.46 | 14.86 |
| | SED | 12.34 | 14.32 | 10.52 | 13.46 |
| | LSD | 0.26 | NS | NS | 0.87 |
| Santa Cruz | Control | 38.25 | 28.71 | 10.52 | 13.62 |
| | Weed control | 37.82 | 32.21 | 12,62 | 15.22 |
| | Fertilizer | 37.22 | 33.23 | 15.22 | 15.32 |
| | Pest control | 36.36 | 32.31 | 13.62 | 15.63 |
| | Mulching | 38.16 | 35.21 | 14.55 | 15.22 |
| | Staking | 37.81 | 34.11 | 15.52 | 14.31 |
| | SED | 12.47 | 10.71 | 12.61 | 14.36 |
| | LSD | 0.98 | NS | NS | 0.88 |

The number of days of fluorescing (flowering) and the fruit yield in tons per hectare (t/ha) were significantly different ($p<0.05$) in all the varieties (Ibadan local Roma, Rotina and Santa Cruz) cultivated in uncontrolled environment (Open field) as seen in table 3 above. The number of fruits per stand and the fruit weight in Kilograms per hectare were not significantly different ($p>0.05$) for all the four varieties cultivated in an uncontrolled environment (Open field) (Table 3).

**Table 4** Effect of Climate Change on the yield in tons per hectare (t/ha) of tomato varieties cultivated in a controlled environment (Green House)

| **Treatments** | | | | | |
|---|---|---|---|---|---|
| **Varieties** | **Cultural practices** | **No of days to flowering** | **No of fruits/stand** | **Fruit weight in kg** | **Fruit yield in t/ha** |
| Ibadan local | Control | 30.00 | 28.62 | 12.62 | 13.52 |
| | Weed control | 28.23 | 28.81 | 13.22 | 16.00 |
| | Fertilizer | 30.11 | 30.22 | 15.61 | 15.81 |
| | Pest control | 28.26 | 33.46 | 15.35 | 15.62 |
| | Mulching | 28.15 | 36.12 | 14.71 | 14.53 |
| | Watering | 30.21 | 28.72 | 15.56 | 15.22 |
| | SED | 12.41 | 14.63 | 12.11 | 10.25 |
| | LSD | 2.22 | 5.41 | 2.06 | 2.26 |
| Roma | Control | 28.56 | 26.72 | 12.66 | 13.58 |
| | Weed control | 28.61 | 29.52 | 13.52 | 13.63 |
| | Fertilizer | 28.51 | 30.22 | 13.46 | 14.72 |
| | Pest control | 29.22 | 31.32 | 15.52 | 15.22 |
| | Mulching | 29.30 | 30.61 | 15.41 | 15.34 |
| | Watering | 30.32 | 28.76 | 14.62 | 15.32 |
| | SED | 25.22 | 20.22 | 10.52 | 12.42 |
| | LSD | 3.36 | 2.65 | 3.08 | 2.60 |
| Rotina | Control | 28.26 | 26.23 | 15.56 | 16.25 |
| | Weed control | 28.22 | 30.33 | 16.22 | 16.31 |
| | Fertilizer | 27.52 | 30.16 | 15.73 | 15.83 |
| | Pest control | 28.66 | 28.56 | 14.86 | 15.72 |
| | Mulching | 28.55 | 28.61 | 15.36 | 15.83 |
| | Watering | 28.62 | 30.22 | 15.28 | 16.23 |
| | SED | 12.53 | 16.43 | 12.32 | 10.25 |
| | LSD | 2.41 | NS | NS | 0.98 |
| Santa Cruz | Control | 30.10 | 27.51 | 14.22 | 15.00 |
| | weed control | 28.36 | 28.66 | 13.56 | 17.28 |
| | Fertilizer | 28.44 | 30.55 | 15.42 | 16.62 |
| | Pest control | 30.21 | 28.78 | 15.26 | 14.88 |
| | Mulching | 28.32 | 28.64 | 14.78 | 14.75 |
| | Watering | 28.52 | 30.22 | 13.56 | 15.22 |
| | SED | 14.34 | 10.35 | 12.26 | 13.35 |
| | LSD | 2.26 | 0.86 | NS | 0.76 |

The analysis of table 4 above shows that the number of days to flowering, the number of fruits per stand, the fruit weight in kilograms per hectare and the fruit yield in tons per hectare (t/ha) were significantly different ($p<0.05$) in all the varieties cultivated under a controlled environment (Green house), except for variety 3 (Rotina) where the number of fruits per stand and the fruit weight in Kilograms were not significantly different ($p>0.05$), and the fruit weight in kilograms per hectare for variety 4 (Santa Cruz) was not significantly different ($p>0.05$).

## 4. Discussion

The effect of Climate Change on agricultural production, particularly on crop production cannot be overemphasized, especially in the dry tropical regions of Africa. The fact that the leaf area index, the stem girth and plant height per stand differ significantly ($p<0.05$) in varieties 1 and 4 (Ibadan local and Santa Cruz), cultivated in an uncontrolled environment here, shows that the growth parameters were affected by the climate change scenarios such as reduced rainfall and increased in the intensities of sunlight. This is in agreement with the views of [11] that the increase in sun hours and intensities per day and the unpredictability of the rains couple with its reduction in intensity is affecting crop productivity in Africa. The stem girth of variety 2 (Roma), the leaf area index of variety 3 (Rotina) and the leaf area index of variety 3 (Rotina) were not significantly different ($p<0.05$) which means that such growth parameters were not affected by the climate change factor (Table 1).

Leaf area index, stem girth and plant height per stand were significantly different ($p<0.05$) in variety 4 (Green house) where environmental factors were regulated including providing adequate water, protection from pests etc. This was in line with [9] that with proper management practices, Santa Cruz Variety of tomato will flourish more than other cultivars. The stem girth and plant height per stand were also significantly different ($p<0.05$) in varieties 1 and 2 (Ibadan local and Roma) as well as leaf Area index and plant height per stand were significantly different ($p<0.05$) in variety 3 (Rotina) (Table 2).

In terms of effect of Climate Change on the yield in tons per hectare of tomato varieties, the number of days to flowering and fruit yield in (t/ha) were significantly different ($p<0.05$) for varieties cultivated in the open field. Flowering was delayed in all the varieties cultivated in the open field. The longest delay was in variety 1 (Ibadan Local) which took between 38.21 to 38.40 days to flower after planting. This was followed by variety 2 (Roma) which flowered in between 38.20 to 38.32 days after planting (Table 3). This is due to intense heat from prolong sun light in the uncontrolled environment (Open field), couple with the unpredictable and low intensity rainfall that characterized the growing season of the tomato cultivars. The yields in all the varieties cultivated in the open field were as low as between 12 and 15 t/ha compared to yields in cultivation in green house where between 16 and 17 t/ha were recorded. This was in line with [12] that the unpredictable rainfall couple with heat from sunlight is disrupting agricultural calendars, racking havoc on agricultural planning and resulting to low yields in tropical Africa. [1] earlier reported declining yields of crops in West Africa as a result of climate change effect. The low yields in open field cultivation in this experiment may also be attribution to climate change secondary factors such as pests and diseases attacks. This is because despite limited pest control measures put in place during the crop growing season, some crops were attacked by pests and diseases in the plots alongside with those in control plots (Table 3).

However, yields in tons per hectare (t/ha) were relatively high in tomato varieties cultivated in the green house. The yields here were between 16 to 17 t/ha. The highest yields were recorded in variety 4 (Santa Cruz) which were 17.28 and 16.62 t/ha (Table 4). This was in line with [9] that Santa Cruz was a high yielding cultivar of tomato amongst others cultivated in Nigeria. Variety 3 (Rotina) also recorded remarkable increase in yield (16.25 to 16.31 t/ha under cultivation in green house. Varieties 1 and 2 (Ibadan local and Roma respectively) also recorded increase in yields of between 15.22 to 16.00 t/ha in green house cultivation (Table 4). [13] had earlier reported higher yields of cultivars such as Santa Cruz, Rotina and Roma in tropical Africa. The higher yields recorded in cultivars cultivated in a Greenhouse was not unconnected with the fact that environmental factors in green house were regulated to mitigate Climate Change effect and pests/diseases as secondary factors of Climate Change were kept under control, although not very sophisticated equipment were installed in the green house, what was available was enough for valuable results.

## 5. Conclusion

Climate Change is already impacting on agricultural production and the entire ecosystem in the dry tropical zones of West Africa including Nigeria and Africa as a whole. There have been alterations in the rainfall pattern and the rains are reducing in amount and intensity year after year. This has led to increasing disruption of agricultural calendars, thereby wreaking havoc on agricultural planning. Farmers must therefore begin to adapt to Climate Change effect in their agricultural practices through methods that will mitigate the Climate Change effect. To do this, requires that they should adopt Climate Smart Agriculture (CSA) which involves activities such as minimum tillage, application of organic manure, crop rotation, mulching to reduce evapotranspiration, composting and planting of legumes and cover crops which will assist in moderating the long-term effects of Climate Change by giving an enduring environmental strength to the soil [14]

### *Recommendations*

The following recommendations were made based of the findings of the research.

- Nigerian farmers must begin to tune their agricultural practices to sustainable forms that will incorporate Climate Smart Agriculture (CSA).
- Most farmers complain that in attempting to adopt Climate Smart Agricultural Principles, the cost of production may be increased as well as increased in drudgery. Government should assist the farmers with credit facilities and equipment that will enable them to practice Climate Smart Agriculture with less stress and at low cost.
- In cultivating tomato, emphases should be on the use of cultivars such as Santa Cruz and Rotina, which appear to be higher yielding cultivars even in the face of Climate Change effect.
- Plant breeders should begin to focus their interest in developing cultivars of crops that will be resilient to Climate Change factors
- Extension workers should be trained on the principles of Climate Smart Agriculture, so that they can in turn go to the rural areas to train farmers on how to adopt the principles of Climate Smart Agriculture.

## Compliance with ethical standards

### *Acknowledgments*

We acknowledged the Federal College of Education, Obudu for granting us access to the institution's Greenhouse and for donating land for the research work

### *Disclosure of conflict of interest*

There was no conflict involving any of the authors or the institutions

### *Statement of ethical approval*

The research was conducted in accordance with ethical standards in the use of the institution's properties as specified by the ethics committee of the Federal College of Education, Obudu.

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