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# Comparative Studies on the Growth, Yield and Industrial Qualities of Five Varieties of Tomato (*Lycopersicon esculentum* Mill.) under Natural and Controlled Environments

*[1]Akinboye O.E., [2]Jegede D.O., [1]Akintunde A.O., [1]Afodu O.J., [3]Makinde A.I.

[1]Department of Agriculture and Industrial Technology, School of Science and Technology, Babcock University, Ilishan-Remo, Ogun State, Nigeria.

[2]Department of Basic Sciences, School of Science and Technology, Babcock University Ilishan-Remo, Ogun State, Nigeria.

[3] Department of Agriculture, Federal College of Agriculture, Ibadan, Nigeria.

*Corresponding Author: akinboyeo@babcock.edu.ng

## ABSTRACT

The objective of this study was to compare the growth and yield indices of five varieties of tomato grown in a screen house with the same five varieties of tomato planted in the field, while also assessing the shelf life and nutritional composition. The Field and the Screen house experiments were carried out at different locations at Babcock University, Ilishan Remo, Ogun State, Nigeria. These locations were to simulate the tomato plant in both natural and controlled environments. Vitamins, lycopene and sugar determinations, proximate analysis and shelf-life assessment were carried out across the two experimental locations. The screen house experiment produced much significant growth indices than the plants in the field experiment with plants having significantly taller plants; more number of branches and leaves and bigger stem girths than plants in the field experiment. The plants in the screen house however had significantly lower yield indices with reduced number of flowers and fruits compared to field plants. The nutritional content however did not vary across both experimental locations attributable to the field component. Findings from the fruits selected from the field experiment showed that until day 14, none of the tomatoes had lost significantly different levels of texture. The most flaccid variety at day 14 was the UC 82-B variety. Similarly, the fruits selected from the screen house experiment, showed mild loss of texture over the 14 days with similar observation. It can be concluded by this study that the growth of the tomato plant is greatly improved in the screen houses. It is recommended that more research be done in a controlled environment to improve yield.

**Keywords:** Tomato, screen house, nutrient, growth, yield, lycopene, crude protein, crude fat

## INTRODUCTION

Tomato is a standout crop and among the most popular produced and extensively consumed vegetable crop in the world [1]. Tomato can be consumed in many ways. The fresh fruits are eaten in salads and sandwiches and as salsa while the processed ones are consumed dried or as pastes, jam, sauces, soups, juices, and beverages [2,3]. Tomato and tomato-based foods give a wide assortment of nutrients and many health-related advantages to the body. Epidemiological studies and other studies associated the consumption of tomato products for the prevention of chronic diseases, such as cancer and cardiovascular disease. Other studies show that tomato products are functional foods and show that lycopene and β-carotene act as an antioxidant.

Tomato production accounts for about 4.8 million hectares of harvested land area globally with an estimated production of 162 million tonnes. China drives world tomato production with about 50 million tonnes followed by India with 17.5 million tonnes [4]. Tomato is a mainstream vegetable in Nigeria. Its production in Nigeria was low, compared to those of nations in the temperate zones. For instance, Nigeria's production was evaluated at 1.8 million tonnes in 2010, while that of the United States of America (USA) was 12.8 million tonnes, putting yield per hectare in Nigeria at 1/7 to that of the U.S.A [5]. Besides, an aggregate of 45% (750,000 metric tons) of tomatoes produced in Nigeria is lost yearly due to the poor food supply chain in Nigeria [6].

The qualityof tomato is subject to numerous preharvest factors, such as, hereditary and natural conditions [7]. Many cultural practices such as quality and quantity of nutrient, water supply, and harvesting methods are additionally accepted to be factors influencing both pre-and postharvest nature of tomato [8]. It is desirable that tomatoes are high yielding and disease resistant, and each cultivar differs in fruit size, shape, taste, colour, and skin and flesh firmness. Tomato is not a drought resistant crop and in this manner yields diminish significantly after brief times of water inadequacy amid production. Appropriate water system planning for tomato generation is consequently essential to the yield advancement [9]. Cultivation of tomato in screen houses need to be given a consistent and controlled supply of water and different nutrients for the proper development and high yield of tomato.

The objective of this study is to compare the growth and yield indices of tomatoes grown in screen house with that of tomatoes planted in the field, while also assessing the shelf life and nutritional composition.

## METHODOLOGY

The experiment was carried in Babcock University, Ilishan-Remo, Ikenne Local Government Ogun State, South-Western Nigeria. Babcock University is located within latitude 6$^{o}$ 54N and 7$^{o}$ 28N of the equator and longitude 3$^{o}$ 42E and 4$^{o}$ 15E of the Greenwich Meridian. The average annual rainfall is 1500mm, with altitude of about 300m above sea level, while the mean annual temperature is about 27$^{o}$C.There were five (5) different varieties of tomatoes selected for this study: Roma VF, U C 82-B, Hausa Local, Beefsteak and Yellow Pear.

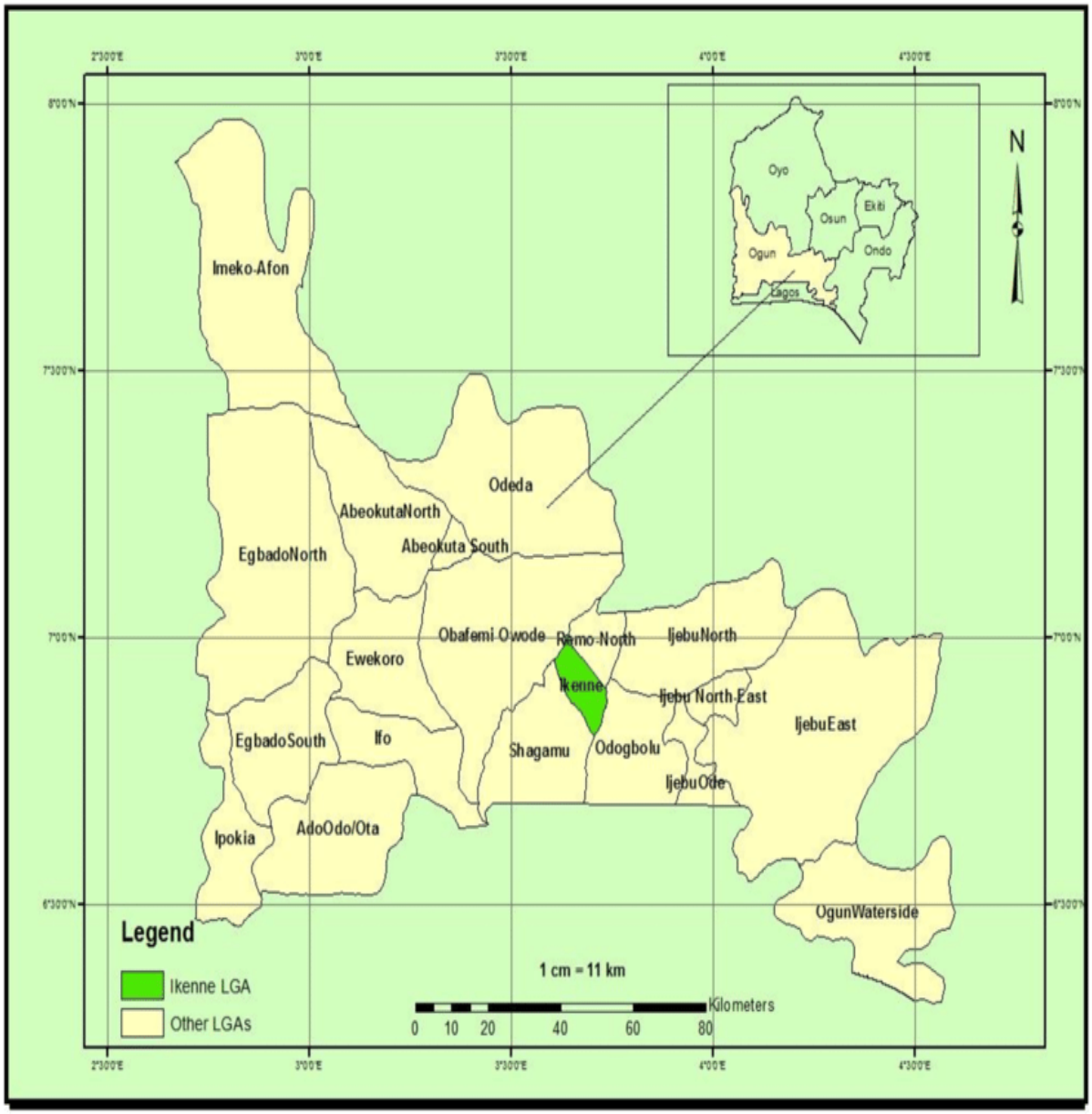


Figure 1. Map of Ogun state showing Ikenne local Government area [10]

**Apparatus:** Major materials used include: Analytical Balance, Digestion Block Heaters, Soxhlet apparatus and accessories, oven, desicator, a Furnace, and Heating mantle.

**Reagents:** Conc .$H_2SO_4$, 0.01NHCl, 40% (w/v) NaOH, 2% Boric Acid Solution, Methyl Red – Bromocresol green mixed indicator, Kjeldahl Catalyst tablet, Petroleum spirit or Ether (40° – 60°C b.pt), Silical gel, grease, 0.255N $H_2SO_4$, 0.313N NaOH, Acetone.

The Field experiment was carried out on a plot of land near the back gate of Babcock University, Ilishan-Remo, Ogun State.

The land was cleared, ploughed and harrowed and beds were made for planting using hoes. Tomato transplanting was done to the field when seedlings were 4 weeks old. The seedlings were transplanted at the spacing of 50 cm x 50 cm (40000 plants/ha). Two seedlings were transplanted per stand and later thinned to one after establishment at two weeks after transplanting (WAT). NPK 15:15:15 was applied to the allotted plots following Bodunde and Adeniji method [11]. Weeding was done manually as the need arose.

| **Letter Notations** | | **Variety of Tomato** |
|---|---|---|
| V1 | = | Roma VF |
| V2 | = | U C 82-B |
| V3 | = | Rio Grande |
| V4 | = | TROPIMECH |
| V5 | = | Roma Savanah |

Table 1: Field Experimental Layout for 5 varieties of tomato

| BLOCK I | BLOCK II | BLOCK III |
|---|---|---|
| V5 | V3 | V2 |
| V4 | V1 | V5 |
| V3 | V4 | V1 |
| V2 | V5 | V3 |
| V1 | V2 | V4 |

The Screen house experiment was carried out in the screen house of Babcock University Department of Agriculture, Ilishan Remo Ogun State. This location was to simulate the tomato plant in a controlled environment. The screen house experiment was carried out to evaluate and recommend a putative variety that performed best in controlled environment.

Five (5) varieties of tomato were evaluated for their growth and yield responses in the screen house. The varieties were evaluated in a Completely randomised design (CRD) with three replicates. Soil moisture was kept at 50% Field Capacity (FC). Morphological and yield data were collected in the screen house. Minimum and maximum temperatures during the experiment period ranged between 22 and 36 °C while relative humidity was between 52 and 96%. Plants were established in large ten litre pots experiments which were laid out in a completely randomized design. Each plant was laid out in 3 replicates, making a total of 15 stands for the 5 varieties of tomatoes used.

The soil for screen house experiment was taken from a plot adjacent to the field where the field experiment was carried out. The soil was classified as Ferric Luvisol with a sandy loam texture, pH (water) of 5.4, organic carbon (OC) 1.26%, total nitrogen (%N) 0.12%, available phosphorus (P) 34.4 mg $kg^{-1}$, calcium (Ca) 5.9 cmol $kg^{-1}$ and magnesium (Mg) 0.7 cmol $kg^{-1}$, Ex. Acidity H+ 0.15 mol $kg^{-1}$, C.E.C 6.38 mol $kg^{-1}$, Org. Matter 2.53%, N 0.15%.

**Proximate analysis**

**Crude Protein Determination (AOAC Official Method 988.05)**

The crude protein in the sample were determined by the routine semi-micro Kjeldahl, procedure/technique. This consists of three techniques of analysis namely Digestion, Distillation and Titration.

About 0.5g of each finely ground dried sample was weighed carefully into the Kjeldahl digestion tubes to ensure that all sample materials got to the bottom of the tubes. To this were added 1 Kjeldahl catalyst tablet and 10mL of Conc. $H_2SO_4$. These were set in the appropriate hole of the Digestion Block Heaters in a fume cupboard. The digestion was left on for 4 hours, after which a clear colourless solution was left in the tube. The digest was cooled and carefully transferred into 100mL volumetric flask, thoroughly rinsing the digestion tube with distilled water and the flask was made up to mark with distilled water.

The distillation was done with Markham distillation apparatus which allows volatile substances such as ammonia to be steam distilled with complete collection of the distillate. The apparatus was steamed out for about ten minutes. The steam generator is then removed from the heat source developing vacuum to remove condensed water. The steam generator is then placed on the heat source (i.e. heating mantle) and each component of the apparatus was fixed up appropriately.

Exactly 5 mL portion of the digest above was pipetted into the body of the apparatus via the small funnel aperture. To this was added 5mLof 40% (w/v) NaOH through the same opening with the 5 mL pipette.

The mixture was steam-distilled for 2 minutes into a 50 mL conical flask containing 10 mL of 2% boric acid plus mixed indicator solution placed at the receiving tip of the condenser. The Boric Acid plus indicator solution changes colour from red to green showing that all the ammonia liberated have been trapped.

The green colour solution obtained was then titrated against 0.01N HCl contained in a 50 mL burette. At the end point or equivalent point, the green colour turns to wine colour which indicates that all the nitrogen trapped as ammonium borate [$(NH_4)_2BO_3$] have been removed as ammonium chloride ($NH_4Cl$).

The percentage nitrogen in this analysis was calculated using the formula:

$$\% N = Titre\ value\ x\ Atomic\ mass\ of\ Nitrogen\ x\ Normality\ of\ HCL\ used\ x\ 4$$

$$or\ \% N = Titre\ value\ x\ Normality/Molarity\ of\ HCL\ used\ x\ Atomic\ mass\ of\ N\ x\ Volume\ of\ flask\ containing\ the\ digest\ x\ \frac{100}{1}$$

Weight of sample digested in milligram x Vol. of digest for steam distillation. The crude protein content is determined by multiplying percentage Nitrogen by a constant factor of 6.25 i.e. % CP = % N x 6.25.

**Crude Fat or Ether Extract Determination (AOAC Official Method 2003.06)**

About 1g of each dried sample was weighed into fat free extraction thimble and pug lightly with cotton wool. The thimble was placed in the extractor and fitted up with reflux condenser and a 250 mL soxhlet flask which has been previously dried in the oven, cooled in the desiccator and weighed. The soxhlet flask is then filled to $^3/_4$ of its volume with petroleum ether (b.pt. 40 ºC – 60 ºC). The extractor plus condenser set was placed on the heater. The heater was put on for six hours with constant running water from the tap for condensation of ether vapor. The set is constantly watched for ether leaks and the heat source is adjusted appropriately for the ether to boil gently. The ether is left to siphon over several times until it is short of siphoning. It is after this is noticed that any ether content of the extractor is carefully drained into the ether stock bottle. The thimble containing sample is then removed and dried on a clock glass on the bench top. The extractor, flask and condenser is replaced and the distillation continues until the flask is practically dry. The flask which now contains

the fat or oil is detached, its exterior cleaned and dried to a constant weight in the oven. The initial weight of dry soxhlet flask is Wo and the final weight of oven dried flask + oil/fat is $W_1$, percentage fat/oil is obtained by the formula: $\frac{W_1 - W_0}{Wt.of\ Sample}\ x\ \frac{100}{1}$

**Dry Matter and Moisture Determination (AOAC Official Method 967.08)**

About 2 g of the sample was weighed into a previously weighed crucible. The crucible plus sample taken was then transferred into the oven set at 100°C to dry to a constant weight for 24 hours overnight. At the end of the 24 hours, the crucible plus sample was removed from the oven and transferred to the desiccator, cooled for ten minutes and weighed.

The weight of empty crucible is Wo

weight of crucible plus sample is $W_1$

weight of crucible plus oven-dried sample $W_3$

$$(\%DM)\%\ Dry\ Matter = \frac{W_3 - W_0}{W_1 - W_0} x \frac{100}{1}$$

$$\%\ Moisture = \frac{W_1 - W_3}{W_1 - W_0}\ x\ \frac{100}{1}$$

$$or\ \%\ \ Moisture = 100 - \ \%D.M$$

**Determination of Ash (AOAC Official Method 942.05)**

About 2.0 g of the sample were weighed into a porcelain crucible. This was transferred into the muffle furnace set at 550ºC and left for4 hours. By this time, it had turned to white ash. The crucible and its content were cooled to about 100ºC in air, then room temperature in a desiccator and weighed. This was done in duplicate. The percentage ash was calculated from the formula below:

$$Ash\ content = \frac{wt.of\ ash}{original\ wt.of\ sample} x \frac{100}{1}$$

**Fiber Determination (AOAC Official Method 958.06)**

About 2 g of the sample was accurately into the fiber flask and 100mL of 0.255N $H_2SO_4$ added. The mixture was heated under reflux for 1 hour with the heating mantle. The hot mixture was filtered through a fibre sieve cloth. The filterate obtained was thrown off and the residue was returned to the fibre flask to which 100 mL of 0.313N NaOH was added and heated under reflux for another 1 hour. The mixture was filtered through a fiber sieve cloth

and 10 ml of acetone added to dissolve any organic constituent. The residue was washed with about 50 ml hot water on the sieve cloth before it was finally transferred into the crucible. The crucible and the residue were oven-dried at 105 ºC overnight to drive off moisture. The oven-dried crucible containing the residue was cooled in a desiccator and later weighed to obtain the weight $W_1$. The crucible with weight $W_1$ was transferred to the muffle furnace for ashing at 550 °C for 4 hours.

The crucible containing white or grey ash (free of carbonaceous material) was cooled in the desiccator and weight to obtain $W_2$. The difference $W_1 - W_2$ gives the weight of fibre. The percentage fiber was obtained by the formula:

$$\% \, Fibre = \frac{W_1 - W_2}{wt.of\ sample(g)} x \frac{100}{1}$$

**Lycopene, Vitamins and Sugar Determinations**

**Determination of Lycopene**

About 1 g of fresh tomato was weighed into a 250 mL beaker and crushed with a glass rod. Exactly 25 mL of HPLC grade acetone was added and shaken for 10 min. Exactly 25 mL of methanolic NaOH solution was added and a reflux condenser attached. The mixture above was heated in boiling water bath for 1hr with frequent shaking. The mixture was cooled rapidly and 50 mL of distilled water added. The hydrolysate obtained was transferred into a separatory funnel. The solution was extracted thrice with 50 mL of HPLC acetone, and 1 g of $K_2SO_4$ added to remove any traces of water. The organic layer was carefully removed into a 250mL beaker and subsequently filtered into a 100 mL volumetric flask and made up to mark with HPLC acetone.

Standard solutions of lycopene of range 0-50 µg/ml was prepared from 100 ppm stock lycopene solution. The different concentrations of lycopene standard solutions were treated similarly like sample. The absorbances or optical density of sample extracts as well as standard solutions of lycopene were taken on a Spectronic 21D Spectrophotometer made by Artisan Technology Group ®101 Mercury Drive Champaign, IL, at a wavelength of 340 nm.

Amount of lycopene in ug/g or mg/kg =

$$\frac{Absorbance\ of\ sample\ x\ Gradient\ factor\ x\ Dilution\ factor}{Weight\ of\ sample\ taken(g)}$$

Data collected were subjected to Analysis of variance (ANOVA). Treatment Means, if statistically different, was separated by Duncan Multiple Range Test (DMRT) at 5% level of significance using the Statistical Package for Social Science (SPSS) version 21.

**Determination of Vitamin C**

About 10 g of the sample slurry was weighed into a 100 ml volumetric flask and diluted to 100 mL with 3% metaphosphoric acid solution (0.0033M EDTA). The diluted samples were filtered using a Whatman Filter Paper No. 3.

About 10 mL of the filtrate was pipetted into a small flask and titrated immediately with a standardized solution of 2.6 dichlorophenol-in-dephenol to a faint pink end point. The ascorbic acid content of the fruit was calculated from the relationship below.

$$\frac{VxT}{W(g)}x100 = mg\ ascorbic\ acid\ per\ 100g\ sample$$

where V = --ml dye used for titration of aliquot of diluted sample.

T = ascorbic acid equivalent of dye solution expressed as mg per mL of dye.

W = gram of sample in aliquot titrated.

**Determination of β-carotene**

Stock solution of beta carotene was prepared by taking 10 mg in 100 mL n-hexane. The concentration of stock solution was equal to 100 ppm. The stock solution was diluted to different known concentrations: 20, 40 and 60 ppm. Dilutions were obtained in 5 mL of each n-hexane solutions. Each working standard solution was injected into HPLC system installed at the Laboratory of Department of Agricultural Chemistry, Peshawar, Pakistan and chromatographic condition was Perkin Elmer HPLC Programme containing LC-1000 pump (Isocratic), having C18 column and connected with LC 250 UV/VIS detector was used. Peak identification and quantification was made by "CSW 32 software" for HPLC system. HPLC was calibrated by running mobile phase (Acetonitrile, dichloromethane and methanol by the ratio of 70:20:10, respectively) at the rate of 2 ml per minute. Wavelength was fixed at 452 nm. The pressure of the column was kept 1800-2000 PSI. Each standard solution (20µl) of beta carotene was injected when the injector was in load mode. The standard beta carotene peak was achieved at the retention time of 4.7 minutes (Rt = 4.7). The concentrations of the beta carotene standards were plotted against the peak area to obtain a straight line.

**Determination of Vitamin B3**

About 5g of sample was blended and 100mLof distilled water added to dissolve all Nicotinic acid or Niacin present. About 5mL of this solution was drawn into 100mLvolumetric flask and made up to mark with distilled water. Exactly 30 ppm of Niacin stock solution was also prepared. The absorbance of the diluted stock solutions and sample extract were measured at a wavelength of 385 nm on a Multiskan SkyHigh Microplate Spectrophotometer, made by Thermofischer Scientific in the United States of America. Different concentrations of standard stock solutions were read on the spectrophotometer for absorbance at the specified wavelength to obtain the Gradient Factor. Amount of Niacin in sample was calculated using the formula:

mg/100 g Niacin = Absorbance x Dilution x Gradient Factor Stock

**Determination of Sugar Content**

About 5 mL distilled water was homogenized with a suitable quality of the fruit juice for 3 minutes. An extract of 100 mL was made in the volumetric flask and centrifuged at approximately 1,000 rpm for 15 min. For sugar content analysis, 15 mL of 1M hydrochloric acid was added and 10 mL of distilled water. This was boiled gently for 3 minutes and cooled in a beaker of tap water and then diluted to 20 mL with water. It was mixed well and the absorbance of each tube was measured in a spectronic 20 apparatus, zeroing with tube 1. A calibration curve was prepared from the results obtained for tubes 2, 3, and 4 by plotting absorbance vertically against moles of glycose plus fructose in each tube as abscissa. The sugar content was obtained from the standard calibration curve [12].

Evaluation of shelf life was done by collection of the best three (3) fruits from each of the five (5) varieties of tomatoes planted. These samples were washed with sodium hypochlorite solution (NaOCl) with a concentration of 100 mg/l as described by Viskelis et al [13]. The fruits were kept under the same conditions of humidity and temperature and they were left on open shelf in a dark and ventilated room. The fruits were checked weekly for the following parameters: Colour change, which was measured on a scale of 1 to 5 with 1 being green and 5 being fully red. The fruit texture was also examined to test for its firmness and then rated on a scale of 1 to 5, with 1 being very firm and 5 being very flaccid. Wholesomeness of the fruit was also measured to identifying decay in the fruits of each variety and this was rated on a scale of 1 to 5, with 1 being no decay and 5 being very decayed. [14]

## RESULTS AND DISCUSSION

Growth and yield of the tomato seedlings were observed for 7 weeks (2WAT to 8WAT) at both the field and screen house. Data were recorded from 2 WAT till the 8 WAT on plant height, number of leaves, number of branches, stem girth, number of flowers and number of fruits.

At the screen house experiment, the Red Cherry, Roma VF and Hausa Local had a higher significant different plant height at 1.76 m, 1.64 m and 1.68 m respectively which were significantly higher than the plants at the field experiment with a significant different maximum heights being 0.84 m, 0.70 m and 0.64 m for the Roma VF, Red cherry and Hausa local varieties. Furthermore, for plants at the screen house, the most significantly different number of leaves was the Yellow Pear variety recording the highest significantly different number of leaves at 70. When compared with plants in the field experiment, the Red Cherry had the highest significantly different number of leaves at 36. Similarly, the screen house experiment plants produced a greater number of branches ranging from 15 to 23 branches while the plants from field experiment had a lower number of branches ranging from 11 to 14 branches. Findings showed no significant difference in the stem girth of plants at the screen house experiment ranging from 17.70 mm to 18.81 mm. However, plants from the field experiment had a bigger stem girth with significant difference ranging from 16.46 mm to 21.31 mm. It was also gathered that the plants from the field experiment recorded a significantly higher number of flowers, between 11 to 21 flowers, than plants in the screen house with flowers ranging from 8 to 9. Number of fruits produced by plants in the field experiment was more than in the screen house experiment with field plants producing as much as 4 fruits (Yellow Pear) while screen house produced 2 fruits (UC82B). The Red Cherry variety however did not produce any fruits at both screen house and field experiments (Table A).

Table A: Growth and yield indices of field and screen house experiments

| Variety | Plant height | Number of leaves | Number of branches | Stem girth | Number of flower | Number of fruits |
|---|---|---|---|---|---|---|
| **Screen House** | | | | | | |
| Roma VF | 1.64a | 43.00b | 16.00 | 18.42 | 8.00 | 0.00 |
| Hausa Local | 1.68a | 50.00ab | 19.00 | 18.30 | 8.00 | 0.00 |
| Red Cherry | 1.76a | 41.00b | 15.00 | 18.81 | 9.00 | 0.00 |
| Yellow Pear | 1.56ab | 70.00a | 23.00 | 17.70 | 8.00 | 1.00 |
| UC82B | 1.22b | 51.00ab | 17.00 | 18.47 | 8.00 | 2.00 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Field Experiment** | | | | | | |
| Roma VF | 0.84a | 26.00c | 11.00c | 16.46c | 19.00b | 1.00 |
| Hausa Local | 0.64bc | 29.00b | 11.00c | 21.17a | 12.00c | 1.00 |
| Red Cherry | 0.70abc | 36.00a | 14.00a | 18.74b | 11.00c | 0.00 |
| Yellow Pear | 0.55c | 32.00ab | 13.00ab | 19.46ab | 21.00a | 4.00 |
| UC82B | 0.72ab | 29.00b | 12.00bc | 21.31a | 12.00c | 1.00 |

**SHELF LIFE**

Findings from the fruits selected from the field experiment showed that until day 14, none of the tomatoes had lost significantly different level of texture. The most flaccid variety at day 14 was the UC 82-B variety. Similarly, from fruits selected from the screen house experiment, fruits showed mild loss of texture over the 14 days' observation (Table B).

As at the day 7 of shelf-life examination, the varieties from the field experiment showed no significant signs of decay. This could be due to the low room temperature (17 $^{o}$C) which limits the multiplication of microorganisms. However, at day 14, UC82B showed the most significant level of deterioration compared to other varieties. This result shows that the Yellow Pear variety is the most economic variety to be cultivated for commercial purposes considering its durable shelf life. This finding was also reflected among the screen house experiment fruits which showed no significant difference from the field experiment fruits (Table B).

Table B: Shelf-life comparison of field and screen house experiments

| **Variety** | | **Texture** | | | **Wholesomeness** | | |
|---|---|---|---|---|---|---|---|
| | | Day 1 | Day 7 | Day 14 | Day 1 | Day 7 | Day 14 |
| **Roma VF** | Field | **5** | **5** | 4 | **5** | **5** | 4 |
| | Screen House | **5** | 4 | 4 | **5** | **5** | 3 |
| **U C 82-B** | Field | **5** | 4 | 2 | **5** | 3 | 2 |
| | Screen House | **5** | 5 | 3 | **5** | 4 | 2 |
| **Yellow Pear** | Field | **5** | **5** | **5** | **5** | **5** | **5** |
| | Screen House | **5** | **5** | **5** | **5** | **5** | **5** |
| **Hausa Local** | Field | **5** | **5** | 3 | **5** | **5** | 4 |
| | Screen House | **5** | **5** | 4 | **5** | **5** | 4 |

**PROXIMATE COMPOSITION**

From laboratory analysis of data taken, it was found that the Roma VF variety had the highest percentage crude protein among the screen house fruits (1.32%) while the Yellow Pear variety had the highest percentage crude protein in the field house fruits (1.19%). There was

no significant difference in the level of percentage crude protein across all the eight (8) samples from both screen house and field experiments at p>0.05(F = 1.299; df = 3; P = 0.390). Further, there was no significant difference recorded in the percentage crude fat across the sample fruits selected for this study at p>0.05 (F = 1.468; df = 3; P = 0.350). The percentage carbon fibre of the fruits was significantly different across the screen house and field experiments. It was revealed that the fruits from the field experiment contained significantly more percentage carbon fibre with the Roma VF and Yellow Pear had a significantly higher value (F = 11.505; df = 3; *P < 0.05*). There was however, no significant difference in the percentage ash (F = 6.137; df = 3; P = 0.056) and percentage moisture contents (F = 3.282; df = 3; P = 0.141) across the selected samples (Table C).

Table C: Proximate composition of fruit across screen house and field experiments

| SAMPLE | %CP | %CFAT | %CFIBRE | %ASH | %M |
|---|---|---|---|---|---|
| **Screen House Experiment** | | | | | |
| Roma VF | 1.32 | 0.23 | 1.01ab | 0.68 | 93.32 |
| U C 82-B | 1.12 | 0.21 | 0.87bc | 0.62 | 94.21 |
| Yellow Pear | 0.97 | 0.19 | 1.01ab | 0.72 | 93.23 |
| Hausa Local | 1.01 | 0.23 | 0.97b | 0.71 | 93.52 |
| **Field Experiment** | | | | | |
| Roma VF | 1.12 | 0.26 | 1.05a | 0.71 | 93.78 |
| U C 82-B | 0.93 | 0.17 | 0.79c | 0.66 | 94.05 |
| Yellow Pear | 1.19 | 0.23 | 1.07a | 0.77 | 93.72 |
| Hausa Local | 0.97 | 0.19 | 1.01ab | 0.72 | 93.23 |

**VITAMINS, LYCOPENE AND SUGAR CONTENT**

In examining the Vitamin C content of the varieties planted in the screen house and field experiments, it was discovered that the Yellow Pear variety had the most significant value at both experiments (F =12.052; df = 3; *P < 0.05*). Furthermore, there was significant difference in the level of ß-Carotene content across the selected samples with the UC82B and Yellow Pear varieties showing a higher significant level of content (F =22.783; df = 3; *P < 0.05*). The least value for vitamin C and ß-Carotene were found in Roma VF in both the screen house and field experiments. Lycopene content did not show any significant difference across the two experiments (F =0.789; df = 3; P = 0.560). B3 content however showed a higher content value among field experiment fruits especially the Yellow Pear and Hausa Local with 0.76mg/100g and 0.73mg/100g respectively (F =8.785; df = 3; *P < 0.05*). There was no

significant difference in the sugar content across the selected samples in both experiments (F =2.094; df = 3; P = 0.244) (Table D).

Table D: Vitamin, Lycopene and sugar content across screen house and field experiment

| SAMPLE | VIT.C (mg/100g) | ß-Carotene (µg/100g) | LYCOPENE (mg/100g) | B3 (mg/100g) | SUGAR % |
|---|---|---|---|---|---|
| **Screen house experiment** | | | | | |
| Roma VF | 13.21bc | 438.87c | 2.125 | 0.59d | 2.51 |
| U C 82-B | 13.94b | 441.24a | 2.345 | 0.69c | 2.42 |
| Yellow Pear | 14.32a | 440.94ab | 2.983 | 0.73b | 2.68 |
| Hausa Local | 13.98b | 439.12b | 2.173 | 0.68c | 3.45 |
| **Field experiment** | | | | | |
| Roma VF | 13.57bc | 438.26c | 2.634 | 0.63c | 2.54 |
| U C 82-B | 14.07ab | 441.31a | 2.612 | 0.66c | 2.48 |
| Yellow Pear | 14.16a | 441.36a | 2.594 | 0.76a | 2.63 |
| Hausa Local | 13.95b | 439.93b | 2.651 | 0.73b | 2.69 |

The screen house experiment produced much significant growth indices than the plants in the field experiment with plants having significantly taller plants and more numbers of branches and leaves and bigger stem girths than in the field experiment. In Australia, most tomatoes are grown outdoors, but there is an increasing preference for the use of closed greenhouses, which results in improved quality while allowing large reductions in the use of water and pesticides [15]. This allows for a better plant growth compared to field cultivation. However, a conventional Nigerian farmer may not have the financial capacity to afford tomato cultivation in a screen house which may limit the potential of recording better quality growth in plant. Outside of the improved growth indices, the plants in the screen house however had significantly lower yield indices with reduced number of flowers and fruits compared to field plants. This might be attributed to the reduced level of pollination in the screen house.

Tomato is naturally self-pollinated [16]. Pollen is shed within the individual flowers during anthesis when there is a strong enough vibrating force, such as wind, to shake the plant and flower [17]. Earlier study opined that insect pollination of field tomatoes is very rare and has no significant effect on fruit set and yield [18]. However, recent study revealed that pollination by *bee* resulted in significantly heavier, seedier tomatoes compared with wind pollination. This might explain the better yield in the field experiment. When tomatoes are grown outdoors, pollination readily occurs through both wind and biotic factors [16, 19], but when grown in greenhouses, special intervention is required to ensure pollen transfer to the

stigma [20]. Pollination methods include shaking the plant or individual clusters either by hand or by an electric vibration wand, and releasing pollinators (bees) inside the greenhouse. This was not implemented in the screen house experiment for this study as widely practiced in developed countries in Europe, the United States, New Zealand, Japan, Chile, and Israel [21].

The nutritional value, colour, and flavour of tomatoes and their products depend mainly on lycopene, β-carotene, ascorbic acid and sugars, and their ratios in the fruits [13]. With a significantly higher β-carotene value in the field experiment fruits, they appeared to be of higher nutritional value. However, there was no significant difference in the sugar and Lycopene values across both experiments. Previous studies have confirmed that the carotenoid content in tomato fruits could be determined by genotypic characteristics [22, 23]. This is reflected in the value presented in both the UC82B and Yellow Pear varieties in both experiments. The sugar amounts in fruits and root crop vegetables depend on plant genotype, meteorological conditions, fertilisation, and soil composition [24-26]. The soil sample used in the screen house was collected from the field. The sugar content levels of the varieties across the experiment were not significantly different. Sugars and acids are particularly important taste constituents of tomatoes. The sugar content of ripe tomatoes averages 3% [27]. The result from this study was similar with an average content value ranging from 2.42 to 2.69%. It was however contrary to another study which reported that the amounts of total sugar varied little for different varieties and ranging from 4.01% to 4.17% [28]. There are high levels of total sugar and dry matter in fruits at the end of tomato ripening. It is however expected that the sugar content increases as it ripens.

## CONCLUSION

Tomato cultivation in screen house provides adequate and needed nutrients for growth of tomato plants. However, it is important for better yield and quality fruits that pollination is put in place either by wind or insects. The nutritional content however did not vary across the experiments and this may be attributable to the soil. However, with β-carotene, the UC82B and Yellow Pear had significant higher value. It can be concluded by this study that the growth of the tomato plant is greatly improved in the screen houses but the absence of pollinators negatively influenced the yield indices.

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