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Research Article

Greenhouse and open-field farming: A comparison through yield and growth parameters investigated in Dar es Salaam, Tanzania

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ABSTRACT

Growth in terms of yield and growth parameters of tomato (*Solanum lycopersicum* L.) plants grown in greenhouse and open fields was investigated in the present study. Growth in terms of height results showed that the p-value was found to be 0.025054. The significant differences were observed in tomato crops grown in two systems at $p < 0.05$. The results facilitated the investigation of other parameters. Growth in terms of width was investigated. The p-value was found to be 0.432449. The result was not significant at $p < 0.05$. Further analysis was conducted to justify why greenhouse cultivation is better than conventional open-field cultivation. Growth in terms of leaf counts justified the greenhouse cultivation, which is much better than the open field. The p-value was 0.036171. The result was found to be significant at $p < 0.05$. Growth in terms of branches of the stem was examined. The p-value was 0.159487. The result was not significant at $p < 0.05$. Growth in terms of flower counts was analyzed. The p-value was found to be 0.196903. The result showed that there were no significant differences between the crops grown in the two systems at $p < 0.05$. Growth in terms of fruit counts was carried out. The p-value was 2897. The result showed that there was no significant difference between the crops grown in the two systems at $p < 0.05$. Except for growth in terms of height and leaf counts, the results of all other parameters had shown no significant differences. It was found through comparison that the soil sample from the greenhouse system had the highest nitrogen concentration. Similar to this, physical parameter study was carried out, and it was found that the greenhouse system had a high pH, high temperature and maximum moisture content. It may be concluded from the result analysis that the reasons for the variations in growth characteristics may be related to the existence of variations in the results of abiotic factors.

INTRODUCTION

Establishment of low-cost Greenhouse creates opportunity for farmers specially in the field of vegetable production without much initial investment. Tomato (*Solanum lycopersicum* L.) cultivation will be very attractive to the farmers if disease-free and high yielding varieties produced in protected cultivation which can results in high profit. The protected cultivation methods can play an important role in managing temperature, relative humidity etc. Over 247,135 tonnes of tomatoes are produced annually in Tanznaia. This represents 51% of the entire production of vegetables [1]. An investigation was done by Ofori et al. [2] to determine the best soilless media for growing tomato cuttings from the axillary stem of tomato plants and to evaluate the agronomic performance of the cuttings under greenhouse conditions. The tomato cuttings were grown on 100% biochar made from rice husk, 100% rice husk, 100% cocopeat, 50% biochar plus 50% cocopeat, and 50% cocopeat plus 50% rice husk. The production and fruit quality of plants grown from stem cuttings and seeds did not, however, differ significantly.

Tomato is considered as a cash crop which contain high protein and rich mineral contents. At present two tomato varieties are being cultivated in Tanzania. These are: Kiboko Duluti and Meru and are the most popular and economically sound to grow and is extensively cultivated throughout the country. However, due to its recurrent rainfall, its cultivation is badly affected by the cool climatic areas and the winter in the plains of Tanzania region.

Green house cultivation was thought to be very non-economic, but in fact it is a costly technique. In Tanzania, shortage of production and improper agricultural conventional methods have resulted in price increase. Low cost poly house technique has been developed for cultivation of vegetable crops.

For successful tomato cultivation, it is necessary for each grower to change the production as economically and efficiently as possible with the highest yield. This can be accomplished by selecting the economical ways like protected poly house and irrigation techniques, organic manures addition, high yielding strains, visually attractive, having disease resistance and resistance to adverse climate conditions. The composition of tomato consists of 8.75 (g/100 g) ash, 94.17 (g/100 g) water, 5.96 (g/100g) carbohydrate, total sugar 50.6 (g/100g) 17.71 (g/100g) total proteins, 34.67 (g/100 g) energy content, 4.96 g/100 g) lipid and pH 3.83 [3]. In Tanzania, the major agricultural practice utilized for tomato cultivation is open field. The farmers believe that the poly houses are relatively high cost and not affordable to establish. The aim of the present study is to search for the possible alternative system, which is readily available and affordable for tomato cultivation.

Since, *Phytophthora infestans* is undesirable fungi and Whitefly (Bemisia tabaci-Gennadius) which are widely found in many croplands and open field of Tanzania, these may be agent cause late blight disease and direct and indirect effects respectively for tomato [4].

Tomato growth has been measured using a variety of techniques. Others are based on understanding raw data [5], while some have depended on subjective considerations, such as expert opinion.

The outcomes fluctuate depending on the indicators employed, and these various approaches can provide various outcomes.

In a greenhouse, tomato plants grew to a height of 175 cm after 166 days, according to research by Chakraborty and Sethi [6]. A study conducted by Alsadon et al. [7] reported that at each harvesting period, fruit and yield characteristics (fruit length, diameter, fresh weight and number, and total yield) were noted. Leaf area index (LAI), leaf area duration (LAD), leaf weight ratio (LWR), stem weight ratio (SWR), fruit weight ratio (FWR), specific leaf area (SLA), leaf area ratio (LAR), net absorption rate (NAR), relative growth rate (RGR), and crop growth rate (CGR) are some of the plant growth indices that were calculated.

The main objective of the present investigation was to compare yields between conventional open field and green house tomato plants, to quantify the growth characteristics to assess its growth and to study the effect of abiotic factors on tomato cultivation.

MATERIALS AND METHODS

Low cost poly house was constructed at St. Joseph University in Tanzania, Luguruni campus (Fig. 1). The highland was located at 6 o 47’31’S and longitude 39 o 5’19 ’ East.

Fig. 1. Low-cost Poly Greenhouse at St. Joseph University, Tanzania

Procurement of seeds

Tomato seeds Tanya were obtained from Dar es Salaam, Tanzania.

Preparation of seedling

Soil bed prepared with farm yard manure and soil (1:1) was used for tomato cultivation. The seed was grown in the open field up to a height of 15 cm and transferred to the green house. The poly house was established with sufficient ventilation and temperature (24°C-28°C) with 80% relative humidity (RH). Effect of physical and chemical factors on tomato cultivation was undertaken to study maximum yields.

The tomato plants from both the green house and the open field were used and growth characteristics after the 13th week of transplantation from the beds for its physicochemical properties. The harvesting period (number of days), growth parameters such as the height in cm, breadth in cm, number of flowers, number of fruits, number of leaves, number of tomatoes, weight of individual tomato obtained from each bed and subjected to estimate chemical analysis of soil such as nitrogen, phosphorous and potassium and pH according to the kit procedure. Efforts were made to estimate the temperature recorded inside the polyhouse and open field, Similarly, relative humidity in the polyhouse and open field to assess its abiotic factors.

Moisture in the soil

The soil sample from each field was weighed and then exposed for 24 hours at 105oC in a hot air oven ("SCIENTEK" make, Memmert type) and the moisture was calculated using the formula.

NPK Analysis

Soil testing kit (Nice chemicals pvt ltd, Kerala, India) procedure was followed for the estimation of N, P K from the soil. This is the first time a kit approach for NPK analysis has been used. Therefore, the present work includes a detailed approach.

Estimation of Nitrogen

Measured 5 CC of soil sample in the soil measuring tube and transferred 25 ml of nitrogen reagent in to the soil sample. It was allowed to shake for 5 to 10 mts. A pinch of decolorizer was added in to the soil mixture. The solution was allowed to filter. The filtrate was added with 2 drops of nitrogen reagent. Colour was developed and compared with standard chart to estimate the amount of total nitrogen

Estimation of phosphorus

Measured 5 gm of soil sample in the soil measuring tube and transferred 25 ml of nitrogen reagent in to the soil sample. It was allowed to shake for 5 to 10 min. A pinch of decolorizer was added in to the soil mixture. The solution was allowed to filter. The filtrate was added with 2 drops of phosphorous reagent. Colour was developed and compared with standard chart to estimate the amount of total phosphorous.

Estimation of potassium

Measured 5 CC of soil sample in the soil measuring tube and transferred 25 ml of nitrogen reagent in to the soil sample. It was allowed to shake for 5 to 10 min. A pinch of decolorizer was added in to the soil mixture. The solution was allowed to filter. The filtrate was added with 2 drops of nitrogen reagent. Colour was developed and compared with standard chart to estimate the amount of total potassium.

Data Examination

Growth measurements and yield assessments were routinely performed, and these parameters are used to justify the greenhouse system as the most promising technology. The mean of three greenhouse and open field tomato harvest slots was calculated based on their growth and yield characteristics. The paired sample t test was used to compare individual crops grown in greenhouses versus open field sites.

Framework for Analysis

The data analysis's findings were tallied and graphically contrasted. The height of the plants was measured using the ruler. A Vernier caliper (cm) was used to measure the fruit's length and width. Manual counting was done for the number of leaves per plant, clusters of flowers, and fruits per plant. A Japanese electronic top loading balance called the "SHIMADZU" was used to calculate the weight (in grams) of each individual fruit.

RESULTS

The physicochemical analysis of open field Vs greenhouse systems

In comparison, the greenhouse system was found to have favorable environmental conditions. Table 1 displays the

outcomes. The results of the soil physical characteristics showed that controlled cultivation conditions existed in the greenhouse soil sample. The % moisture content of the open field was 19.14 in the day time whereas the greenhouse system showed 24.76. Similarly, open field showed 6 pH, moderate temperature of about 22 C (Table 1).

The N results of greenhouse was calculated to be 150 Kg/ acre and which is maximum when compared with the open field 50 Kg/acre. On comparison, it was seen that the soil sample of the greenhouse system had the maximum nitrogen content. Similarly, physical parameter analysis was carried out and it was found that the atmospheric conditions of the greenhouse had the high pH, maximum moisture content and high temperature.

Characteristics of growth and yield

The effect of growth on greenhouse tomatoes in terms of height, width, number of fruits, number of flowers, and leaf count was compared to the open field. In comparison to crops grown in open fields, the mean average growth parameters of tomatoes grown in greenhouses produced the best results (Table 2 and 3). In comparison, the outcome validated the efficiency of the greenhouse system.

Growth height comparison

The height measurements show that the greenhouse tomato crop reached a maximum height of 141 cm after the 13th week of transplantation and a minimum height of 95.50 cm. The open field was found to be 68 cm (Fig. 2).

Greenhouse grown plants reported higher levels of growth in terms of height than the plants found grown in the open field. T(3)= 2.77432, The p-value is .025054. The result is significant at $p < .05$. Thus, significant differences are found. The measurement of tomato plant width revealed a maximum of 89 cm in the greenhouse system and 80 cm in the open field. The average width in the greenhouse was found to be 70.0±29.51 cm, compared to 66.67±11.93 cm in the open field (Fig. 3). Wind breeze, humidity, differences in soil physical properties, and differences in environmental climatic conditions all played important roles. Greenhouse grown plants reported lower levels of growth in terms of width than the plants found grown in the open field. T(3)= 0.18137, The p-value is 0.432449. The result is not significant at $p < .05$. Thus, significant differences are not found.

Fig. 4 illustrates the mean average differences in the growth characteristics of the tomato plants cultivated under greenhouse vs open field. The mean average height of greenhouse tomato was found to be 109.17±28.17 cm. The open field was found to be 61.67±9.29 cm. Similarly, the mean average differences in the growth characteristics of the tomato plants grown under greenhouse VS open field was investigated. In greenhouse, it was found to be 70±29.51. In open field it was found to be 66.67±11.93 cm.

The leaf counts characteristics

Based on the number of branches analysis, it was determined that the greenhouse crops produced good results, with maximum counts reaching 30 numbers, while the open field produced 19 numbers only (Fig. 5). Greenhouse grown plants (Fig. 6) reported lower levels of growth in terms of stem branches count than the plants found grown in the open field. T(3)= 1.1315, The p-value is .159487. The result is not significant at $p < .05$. Thus, significant differences are not found.

Table 1. The physicochemical parameters of open field Vs greenhouse systems.

Sl. No.	N Kg/ acre	P Kg/ acre	K Kg/ acre	pH	Moisture %	Temp °C
Greenhouse	150	4	50	8.85	24.76	30.05
Open Field	50	4	50	6	19.14	22

Table 2. The growth characteristics of tomato plants grown under greenhouse systems.

Length in cm	Width in cm	Flower in cm	Fruits in nos.	Branches in number	Leaves in number
87.5	89	23	11	19	195
141	85	14	20	30	490
99	36	18	5	19	178
109.17±28.17	70±29.51	18.33±4.5	12±7.54	22.67±6.35	287.67±175.43

Table 3. The growth characteristics of tomato plants grown under open field systems.

Length in cm	Width in cm	Flower in cm	Fruits in nos.	Branches in number	Leaves in number
51	57	10	8	15	303
68	80	13	7	19	417
66	63	12	6	22	336
61.67±9.29	66.67±11.93	11.67±1.5	7.0±1.0	18.67±3.5	352±58.67

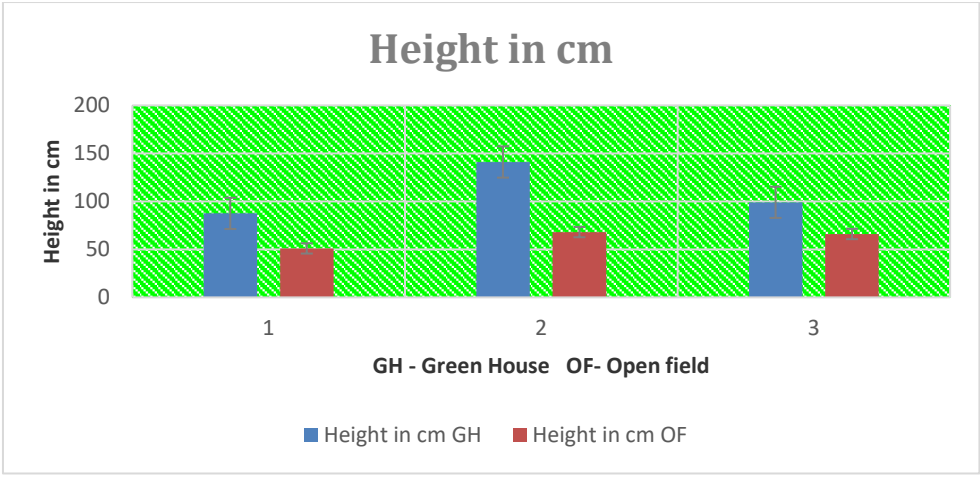

Fig. 2. Tomato plant height of the greenhouse Vs open field systems.

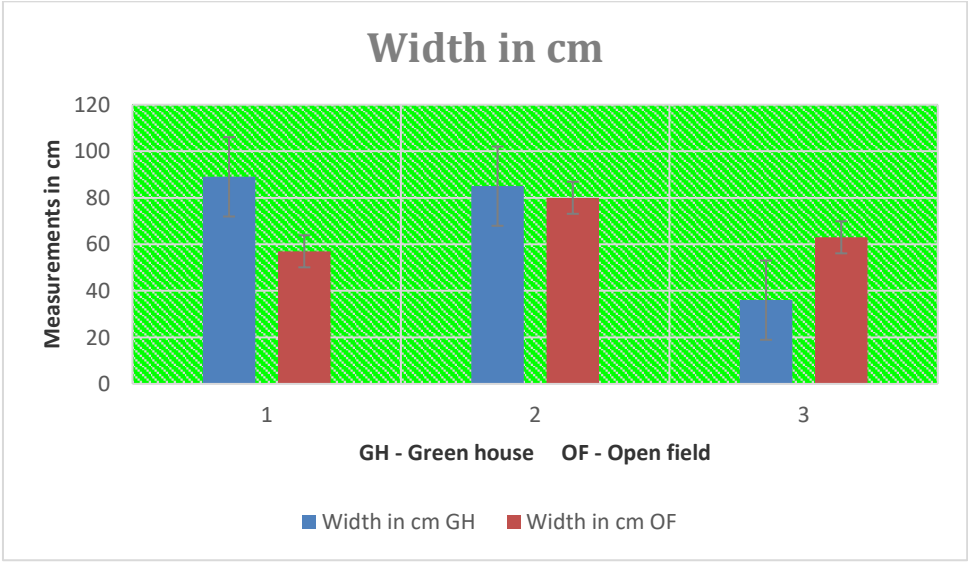

Fig. 3. Tomato plant width of the greenhouse Vs open field systems.

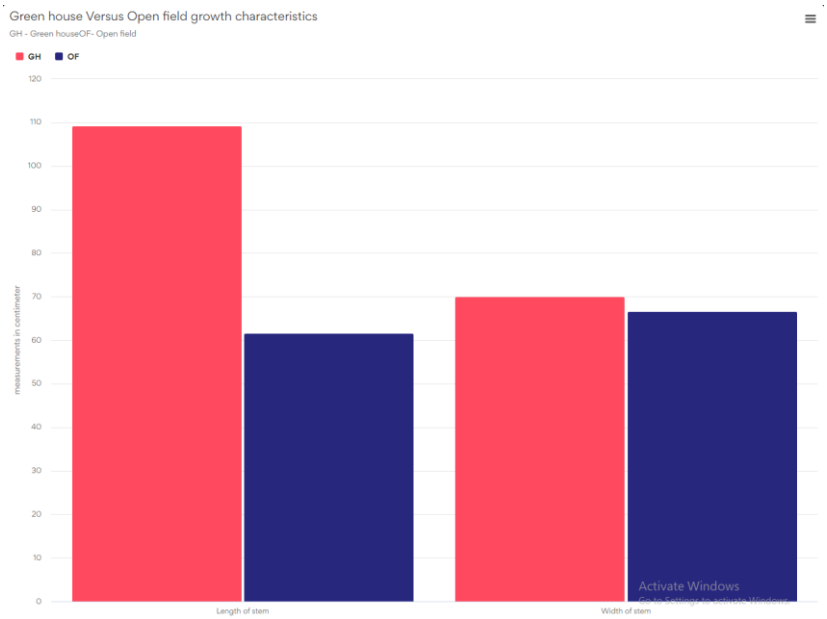

Fig. 4. Tomato plant mean average length and width of the greenhouse Vs open field

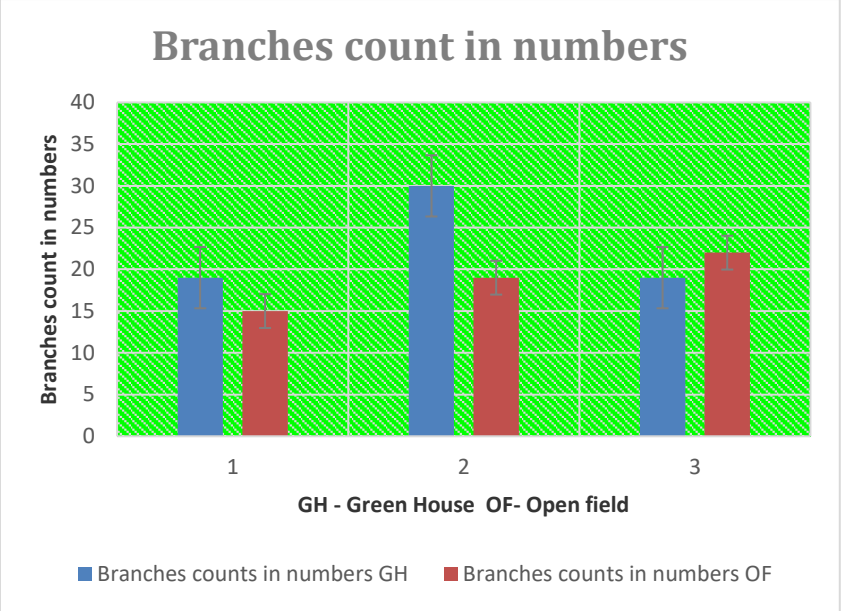

Fig. 5. Tomato plant branches of the stem of the greenhouse Vs open field systems.

The leaf counts characteristics

Based on the number of leaf counts analysis, it was determined that the greenhouse crops produced good results, with maximum counts reaching 490 numbers, while the open field produced 417 numbers only (Fig. 7). Greenhouse grown plants reported higher levels of growth in terms of leaf counts than the plants found grown in the open field t(3)= 2.42536, The p-value is .036171. The result is significant at $p < .05$. Thus significant differences are found. The plants in open field are shown in Fig. 8.

The flower counts characteristics

The flower count results revealed a maximum of 23 in the second slot of the greenhouse system and 13 in the open field. The average number of flowers counts in the greenhouse was 18.33±4.5, while 11.67±1.5 were recorded in the open field (Fig. 9). Greenhouse grown plants reported lower levels of growth in terms of flower counts than the plants found grown in the open field. T(3)= 0.95467, The p-value is .196903. The result is not significant at $p < .05$. Thus significant differences are not found.

The mean average fruit obtained (Fig. 10) per plant in the greenhouse system was 12.0±7.54 compared to 7.0±1.0 in the open field. The greenhouse produced fruits that were slightly longer and wider. In an open field, the shortest and narrowest fruits were obtained with length and width measurements (Fig. 11).

Fig. 6. Tomato plants of the Greenhouse.

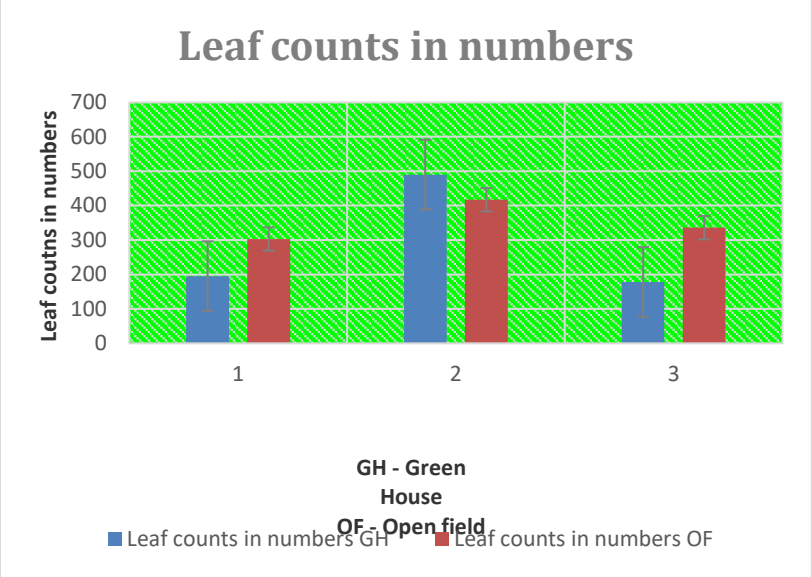

Fig. 7. Tomato plant leaf counts of the greenhouse Vs open field

Fig. 8. Plants grown in Open field.

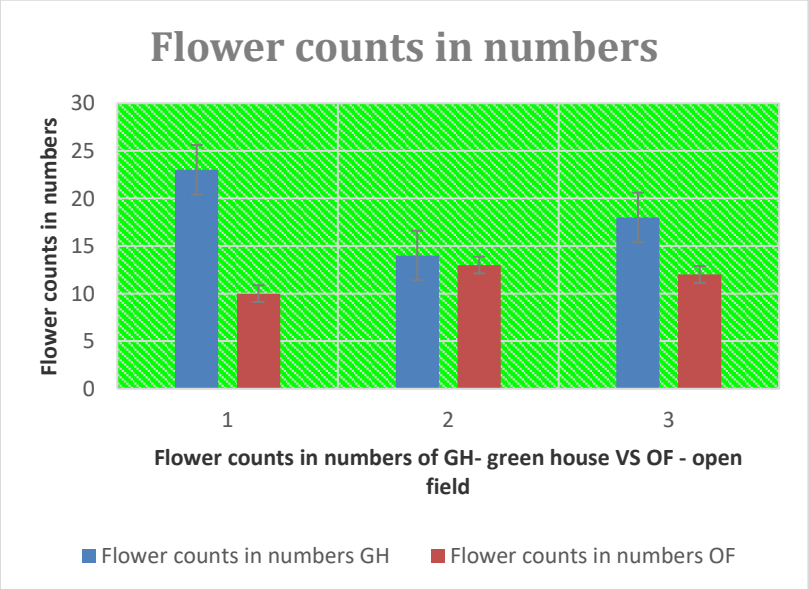

Fig. 9. Tomato plant flower counts of the greenhouse Vs open field systems

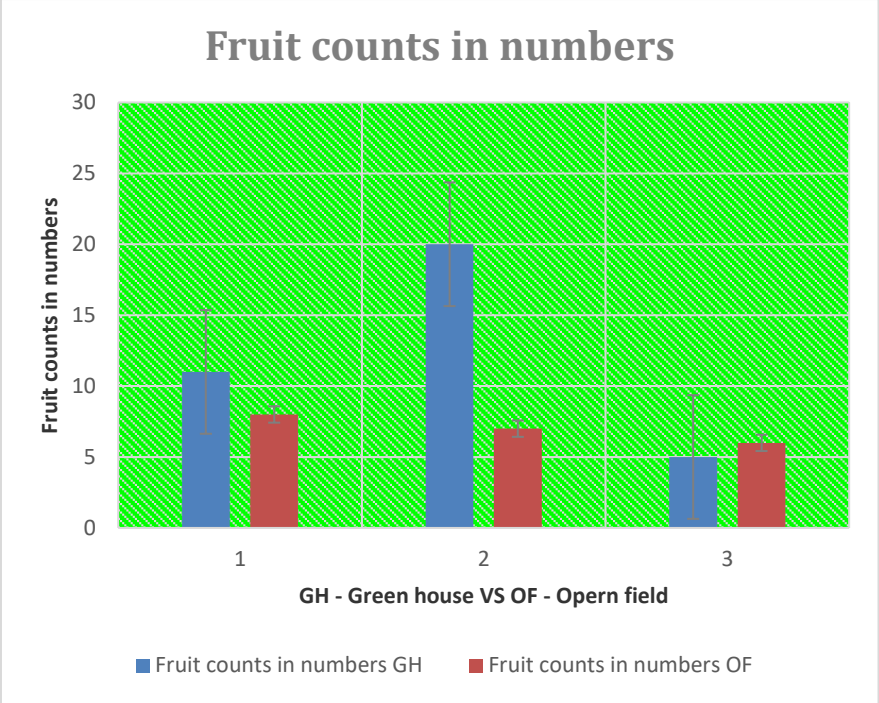

Fig. 10. Tomato plant fruit counts of greenhouse Vs open field systems

Greenhouse grown plants reported lower levels of growth in terms of fruit counts than the plants found grown in the open field. T(3)= -0.60238, The p-value is .2897. The result is not significant at p < .05. Thus the significant differences are not found. The greenhouse system produced the highest average fruit weight of 76.68 g, followed by the conventional open field system, which produced only 51.24 g. The average weight of greenhouse fruits was 74.93 g, while open field fruits were 51.05 g. (Fig. 10).

Fig. 11 illustrates the mean average differences in the growth characteristics of the tomato plants cultivated under greenhouse vs open field was investigated. The mean average flower count of greenhouse tomato was found to be 18.33±4.5. The open field was found to be 11.67±1.5. Similarly, the mean average differences in the fruit counts, leaf counts and branches count, characteristics of the tomato plants grown under greenhouse VS open field were investigated. In greenhouse, fruit counts was found to be 7.549834435. In open field it was found to be 7.0±1.0.

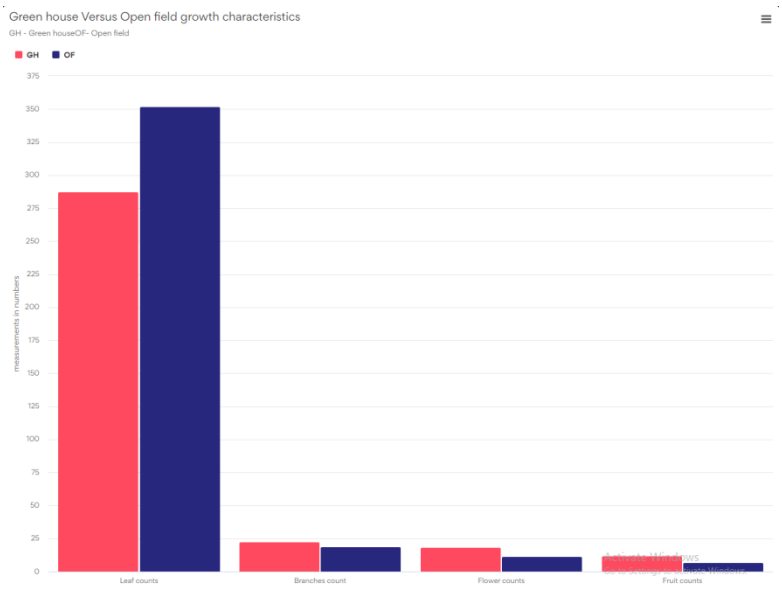

Fig. 11. Tomato plant mean average flower, fruit, branches and leaf counts of GH and OF

Discussion

A variety of microbial pathogens and arthropods pose the greatest threat to the tomato crop from the time the seed germinates until it is ready for harvest. Open field tomato plants are constantly threatened by beetles during the early stages of vegetative growth. Pests that reduce yield in open field conventional methods such as uncertain weathering conditions, hottest temperature, recurrent wind and sudden rain, etc. were frequently to blame. According to Minja et al. [8], due to pests, illnesses, deteriorating soil fertility, severe heat, drought, and excessive heat in eastern Tanzania, tomato productivity is low, particularly in the coastal zone. This is also because the present cultivars have low genetic potential. Cultivars that can withstand stress and are suited to the local environment can boost productivity.

The physiological differences between greenhouse and open field tomatoes were surprisingly large. The physiological characteristics of greenhouse vs. open field tomatoes revealed surprisingly large differences in length, width, leaf count, flower count, and yield. The findings confirmed that abiotic parameters such as temperature, soil moisture, and pH are critical for soil fertility. These findings suggested that the maximum yield characteristics of the greenhouse grown tomato cultivation system could be attributed to the controlled environmental conditions. According to Baudoin et al. [9] tomato production is limited in air temperatures above 30°C and less in relative humidity. The findings are consistent with those of Chakraborty and Sethi [6]. Rosa et al. [10] identified fertilizer application as a critical factor in increasing yield in greenhouse rather than conventional systems. The greenhouse-grown tomato crops had received optimal temperature and soil characteristics, resulting in better growth and yield characteristics than the open fields. Shorter plant height and width, fewer branches and leaves, and lower yield are all symptoms of adverse dynamic climatic conditions in the open field tomato. Wani et al. [11] found that environmental differences in the open field and greenhouse environments played a significant role in the creation of genetic diversity among *Madhura indica* GMEL.

In the current study, the southern side planted plants outperformed the northern side tomato plot. The reason may be due to the presence of tree shade in the northern side slots which masked the availability of intensity of sunlight. The Eastern side slot is away from the window and ventilation could be an issue of poor air circulation and the reason for decreased growth. The reason for the poor growth of open field tomato is due to the presence of uncontrolled environmental conditions. This could explain why the tomato crops grown in the greenhouse produced the best results. Chakraborty and Sethi [6] demonstrated that after 166 days, tomato plants reached a height of 175 cm in the greenhouse. However, the current study's results differ from theirs in that the greenhouse tomato crop in the current study measured 141 cm after 91 days. The day variation revealed significant differences in growth height.

According to Davis et al. [12], tomato plant was grown to a height ranged from 122 to 137 cm. He reasoned that the height of the plant in the greenhouse was determined by the nutrient composition used in their study. Ali et al. [3] conducted a similar study in terms of fruit length and width, reporting 7.48 cm length and 5.08 diameter of fruits, with large fruits totaling 15, medium fruits totaling 11.6, and small fruits totaling 12. The fruit numbers per plant of the present study agree with the findings of Ali et al. [3], who found a maximum of 33.67 fruits per plant.

Salicylic acid (200 ppm) significantly increased the growth parameters, yield, and resistance of tomato plants to wilt disease when grown in a greenhouse [13]. In the current study, the open field grown tomato plants grew stunted and produced a low yield. According to Figàs et al. [14], fruits grown in greenhouses had higher antioxidant activity, soluble solids content, fructose, glucose, and dry matter ascorbic acid concentrations, but lower -carotene and lycopene content than those grown in open fields.

Previous research found an average yield of 1.10 kg in the greenhouse and 0.45 kg in the open field [6]. The average yield in the greenhouse was 2 kg per plant, whereas the yield in the open field was 660 gms. The correlation matrix of greenhouse grown leaves and tomato crop width was 0.473 and 1.000, respectively, indicating that the value was greater than 0.422 and 0.000 (p value 0.01% significance). As a result, the correlation is significant at the 0.001 level.

CONCLUSION

Many environmental parameters are being tested for their effective growth characteristics. Physical and chemical factors are vital to prove their potential role. The greenhouse technology is the least explored was taken for the present study. After the preliminary physio chemical parameters both physical and chemical analysis, the grown plant was subjected to height, width, number of branches, leaf counts, flower counts and fruit counts using the ruler. The supportive statistical results facilitated the significance of the greenhouse technology. Based on the statistical results of leaf counts and height analysis, it can be concluded that the greenhouse technology facilitated the optimum growth conditions. The greenhouse facilitated the controlled environmental conditions and justified the importance of controlled environmental conditions for the maximum growth characteristics.

Therefore, it is suggested that the greenhouse tomato plants can be further evaluated to check for other parameters such as intensity of sunlight, wind flow, relative humidity etc. Entrepreneurs can cultivate protected greenhouse tomato in their native places and they can sale the tomato to the local markets. Different types of tomato varieties could be cultivated to attract the people since it is a money yielding crop. It has plenty of proteins along with minerals and vitamins. The result findings confirmed that physiological parameters of soil such as nitrogen, phosphorous, potassium, temperature, soil moisture and pH are playing crucial role for the yield. The greenhouse facilitated the controlled environmental conditions and justified the importance of controlled environmental conditions for the maximum growth characteristics.

Author Contributions

James M Chacha - Leading the team and did statistical analysis, Murugan thuirumalai – Open field in charge Co-Guide, Obeid K Idawa - ploughing and irrigation work, Josephine Patrick Chilwea - Establishment of greenhouse, Concheska Jelemia Kilamba – Data collection, Bertha D Hussy – Fertilizer and insecticide spray and monitor plant growth, Haania Ishaq - Guidance for establishment of green house and IBM SPSS analysis work, Kalidoss Rajendran - Write up of manuscript – Guide/Supervisor.

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