UNIVERSITY OF EDUCATION, WINNEBA

EFFECTS OF GREENHOUSE TECHNOLOGY ON THE GROWTH AND YIELD OF TOMATO IN THE TRANSITIONAL ZONE OF GHANA

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EFFECTS OF GREENHOUSE TECHNOLOGY ON THE GROWTH AND YIELD OF TOMATO IN THE TRANSITIONAL ZONE OF GHANA

BY

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A THESIS IN THE DEPARTMENT OF CROP AND SOIL SCIENCES EDUCATION, FACULTY OF AGRICULTURE EDUCATION SUBMITTED TO THE SCHOOL OF RESEARCH AND GRADUATE STUDIES, UNIVERSITY OF EDUCATION, WINNEBA IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF EDUCATION (M. Ed AGRICULTURE) IN THE UNIVERSITY OF EDUCATION, WINNEBA

MARCH, 2022

DECLARATION

STUDENT'S DECLARATION

I hereby declare that this research work is the result of my own work under supervision and that it has neither in whole nor in part been presented elsewhere, with the exception of references from other people's work which have been cited and acknowledge accordingly.

…….. …….

ABUGRI, DAVID ATIIWIN **DATE**

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of this project work was supervised in accordance with the guidelines in supervision of project work as laid down by the University of Education, Winneba.

…….. …….

MR. EMMANUEL KWASI ASIEDU **DATE**

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DEDICATION

I dedicate this dissertation to my father Ayaaba Abugri in blessed memory, my mother Asore Nmabun, Labillah Elizabeth Lariba (wife) and Abugri Destined Apiawin Azumah, Abugri Delphine Adelwin Asibi and Abugri Delphina Awinbun Ateni (children) and my siblings for the words of encouragement, prayers and support in completing this course of study.

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ABSTRACT

Greenhouse technology has become a widely accepted and profitable system for vegetable (tomato) production particularly in Ghana. With the increasing demand for tomatoes on daily basis, there is the need to increase productivity. However, the production of tomato in Ghana is limited by harsh climate, drought, capital and inadequate knowledge on the use of modern methods such as greenhouse technology. Hence, the purpose of the study was to investigate the effect of greenhouse technology on the growth and yield of tomato in the transitional zone of Ghana. The experiment was conducted at the Multipurpose Crop Nursery, of the former University of Education, Winneba now AAMUSTED -College of Agriculture Education Mampong campus from 19th August, 2019 to 30th November, 2019. The experimental design used for the study was Randomized Complete Block Design (RCBD) with two treatments made up of greenhouse technology and open field. Parameters measured included: plant height, number of branches, stem girth, number of flowers, number of fruits harvested, harvested fruit weight, matured vertical fruit length and diameter and economic analysis. The data collected were analyzed using the Students T-test using GenStat version 11.1 (2008). Results from the study showed that plant height, number of branches and stem girth were significantly higher ($P<0.05$) among tomato plants grown in the open field as compared with tomato plants grown under the greenhouse technology. Number of harvested fruits, harvested fruit weight, matured vertical fruit length and diameter were significantly ($P<0.05$) highest among tomato plants grown under the greenhouse technology as compared with tomatoes plant grown in the open field. This study concludes that greenhouse technology increased the yield of tomatoes with higher economic returns. The study recommends that farmers should adopt greenhouse technology, since it gave higher productivity and economic returns.

LIST OF ABBREVIATIONS

AAMUSTED	Akenten Appiah- Menka University of Skills Training and Entrepreneurial Development
LSD	Least significant difference
RCBD	Randomized complete block design
CAGR	Cumulative Annual Growth Rate
MoFA	Ministry of Food and Agriculture
WAP	Weeks after planting
DAH	Days after harvesting
VCR	Value-cost ratio
pH	Power of hydrogen
EC	Electrical conductivity
CEC	Cation Exchange capacity
WAPP	West Africa Productivity Programme
WECARD	West and Central African Council for Agricultural Research and Development
PVC	Polyvinyl chloride
MT	Metric tonnes

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Tomato is one of the most important fruit vegetables in the world, and its production is believed to promote food and economic activities of man (Mirabella *et al.,* 2014). According to the Guan *et al.* (2017), China is the leading producer of tomatoes, followed by the United States of America. Donkoh *et al.* (2013) noted that, the commercialization of the tomato industry saw the day light due to the economic reforms and trade liberalization policy pursued by Ghana in the early 1980's and stressed that, the commodity will still remain one of the most important income generating vegetable crops in the country (Whitfield, 2011). The crop is cultivated continuously throughout the year because apart from the rain-fed system that normally spans between March and November in the southern part of the country, there is the dry-season farming system between October and April (Limantol *et al.,* 2016). Despite the fact that the commodity is produced throughout the year, supply falls short of demand, resulting in importations to supplement the shortage (Hochman *et al.,* 2014).

The Brong Ahafo Region is one of the most important tomato producing regions in the country (Aboagye-Nuamah *et al.,* 2018). Techiman and its environs are the major suppliers of tomatoes to the Tamale Metropolis in the wet season while the Upper East Region and Burkina Faso supply the metropolis and Southern part of Ghana during the dry season. Tomato is an annual, biennial, or tender perennial; but it is mostly grown as an annual crop. Presently, tomato is cultivated around the world in greenhouses to facilitate growth in all climates and year-round production (Naseer *et al.,* 2022). The reason accounting for the high importation of tomatoes to Ghana is because the tomatoes imported are bigger,

firmer, far superior in quality and last longer in storage compared to the locally grown tomatoes that have high water content, a lot of seeds, poor coloration, and low total pulp. Tomato has many health benefits including improving the skin, inhibiting several types of cancers, strengthening bones, providing the body with special antioxidants, among several others (Naseer *et al.*, 2022).

In recent times greenhouse technologies (i.e. Envirodome) have been introduced into the country and are now in use for vegetable production (Forkuor *et al.*, 2022). The most common vegetable currently cultivated in these greenhouses is tomatoes with the objective to minimize post-harvest losses (Gruda *et al.*, 2018).

Under the new government planting for Food and Jobs Policy the use of greenhouse technology is being encouraged (Ali *et al.*, 2017). Tunnel house tomato harvest begins about mid-July and field harvest about August 1st. Production of tomatoes in tunnels continues as long as it's economically viable, up to late October. Quantity of yields of ripe tomatoes differ differently with the weather. This range is 10,000 to 30,000 kg per hectare. Tomatoes for green house may produce as much as 40,000 kg per hectare (Ali *et al.*, 2017).

There is a large market for red tomatoes in the Atlantic area within the growing season, especially on the wholesale market (Flores & Villalobos, 2018). There is still price competition from other areas of North America, and in good growing seasons there are local market "gluts" (Chatha & Butt, 2015). There is also interest in extending the season with the use of tunnel houses for July and August production. There is a limited market for fresh green tomatoes and a limited processing facility (Chanda *et al.*, 2021). "Sun

dried" tomatoes are being processed on a small scale. The warmest areas of the Atlantic Provinces can grow red processing tomatoes (Hoenig, 2018).

1.2 Problem Statement

According to Zant (2018), the price of tomatoes has been at constant increase at a faster rate than all commodities with the exception of groundnuts. Wholesale prices have more than trebled in real terms between 2003 and 2012. This reflects strong demand coupled with a failure of domestic production to keep pace with the increase demand (Mogollón *et al.,* 2018). Also, Ghana imports large amounts of processed tomato mostly from Italy (36%) and China (18%), retailing currently at GH₵ 9.41 per kilo in open markets and supermarkets. In response to high volumes of imported processed tomato paste/concentrate to Ghana at Cumulative Annual Growth Rate (CAGR) of 38% from 2002 to 2012, a Foreign Investor, Trusty Foods Ltd., imported bulk tomato pastes and repackaged in smaller units under the brand name “La Bianca. Currently Olam International has purchased the facility from Trusty Foods and is promoting its brand “Tasty Tom” using the same facility and systems located in Tema. Some Ghanaian importers have in collaboration with companies in Italy and China developed brands such as “Obaapa” tomato paste which are solely produced and processed in the countries for sale in Ghana. The study therefore seeks to investigate the effect of green house on the growth and yield of tomato. There is the need to increase the production of tomatoes to meet the growing demand for the crop and the inadequacy of storage facilities (Asgedom, 2011).

1.3 Purpose of the Study

The main objective of the study is to compare the effect of greenhouse and open field environments on the growth and yield of tomato fruits (Lycopersicon esculentum).

1.4 General Objective

The effects of greenhouse technology on the growth and yield of tomatoing the transitional zone of Ghana

1.4.1 Specific Objectives

The specific objectives of the study were:

a) to assess the effect of greenhouse environment compared with the open field tomato
b) to assess the effect of greenhouse compared with the open field yield and fruit quality of tomato
c) to evaluate the economic potential of tomato production in the greenhouse compared with that in the open field

1.5 Significance of the Study

The study will open up important information on the effect of greenhouse and open field environments to improve conditions and increase growth and yield of tomato. The findings of this study will also encourage farmers to select the appropriate environment to maximize growth and yield of tomato production.

Again, scientists can use the results for further studies on tomato. Agriculture teachers can also use this result to teach their students how best the appropriate environment can increase crop production.

The study would also increase tomato production and lead to improvement in household income in Ghana. Besides, an increase in tomato production throughout the country resulting in glut improves food security.

There is cut down of importation and conservation of foreign exchange due to increase local production of tomato and tomato products.

Recommendation from the study will lead to increase in local which will make tomato production more attractive to reduce rural-urban migration among the youth.

1.6 Limitation

The main limitation of this research is that it is very expensive in terms of time, tools, equipment and capital.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin and Distribution

Tomato (*Lycopersicon esculentum*) belongs to the genus Lycopersicon under family Solanaceae along with Irish potatoes, peppers and eggplants (Rasul *et al.,* 2019). *Lycopersicon esculentum* is a perennial plant in the tropics but in northern climates it is grown as an annual. Botanically this vegetable is a fruit (a berry) (Neuhouser *et al.*, 2003). Most cultivars produce red fruits when ripe. Tomato is a native to Peruvian and Mexican region. Though there are no definite records of when and how it came to India, the Portuguese perhaps introduced it to India. The period of growth between emergence and flowering is known as the vegetative phase of plant development (Sulistiawati *et al.*, 2017). During the vegetative phase, plants are busy carrying out photosynthesis and accumulating resources that will be needed for flowering and reproduction. The stem girth can grow to about 2 to 4cm long (Wies *et al.,* 2019) and has dense lateral and adventitious root systems (Bellini *et al.,* 2014).

For many years after its discovery, it was grown as an ornamental; it was not until the 16th Century that it was first accepted as a vegetable crop in the Southern part of Europe (Haye *et al.,* 2015).

Tomato is one of the major vegetables on the world market and forms an essential part of human diet (Haye *et al.,* 2015). It is mostly cultivated on large scale under greenhouse and open field conditions (Figàs *et al.,* 2018). Some people believe that the origin of domestication of tomato is from Peru, while others believe that it originated from Mexico (Haye *et al.,* 2015).

According to Denevan (2001) tomato is a native of the Peru, Bolivia, and Ecuador area of the Andes Mountains. Its antiquity is uncertain in regard to cultivation but it was being cultivated when America was discovered by Europeans. It was not until 1835 that the tomato was considered suitable as a food crop in the northeastern United States.

Tomato plant was first introduced into West Africa, Eastern Africa, and Central Africa during the 16th and 17th centuries Jones, 2020). It is extensively cultivated in Burkina Faso, Nigeria and Ghana (Robinson & Kolavalli, 2010).

In Ghana, it is a common ingredient in the daily diet of people across all regions. Tomato alone accounts for 38% of total vegetable expenditure in Ghana. An exclusive rural-based smallholder production dominates the sub-sector as such their participation in commercial market holds considerable potential for unlocking suitable opportunity necessary for providing better incomes and sustainable livelihoods (Holdsworth *et al.,* 2020). Commercial production is intense in the Upper East, Brong Ahafo, Northern and Greater Accra Regions of Ghana which supply the market at various times of the year. (Robinson & Kolavalli, 2010). Tomato production in Ghana is highly seasonal, reflecting differences in access to water and rainfall patterns (Robinson & Kolavalli, 2010).

Production is largely carried out on family land and/or rented land of relatively small sizes (1-3acres) (Anang *et al.,* 2013). Farmers occupy the same piece of land for several years and have no intention to leave to different places when they realize decrease in yields due to scarcity of land (Melomey *et al.,* 2020).

There are over 7,500 varieties of tomatoes discovered and cultivated for various purposes (Grandillo *et al.,* 2011). They are therefore classified by the shape, size and use. These classifications included the cherry, beefsteak, plum, globe and grape (Adejuwon, 2017). Some examples are Roma VF, Laurano, Raki, Chocó TP, Power Reno, Rasta, Italy Heinz and Petomech (Adejuwon, 2017).

2.2 Botany

Tomato plants have soft, hairy and woody stems. Attached to this stem is its compound leaves made of spirally arranged leaflets which are oblong or ovate (Dharani, 2011). This is the phase of plant life cycle where flowers, fruits and seeds are formed. Tomato has a fleshy fruit and is variable in length, shape and diameter. The fruits are formed from superior ovaries with 2-9 locules. At the mature stage the coloration of the fruit changes from green to red, orange or yellow depending on the variety of tomatoes (Anderson, 2019).

Flowers are generally borne in clusters of 4 to 8 but small fruited types may have 30 to 50 flowers per cluster. The flowers are mainly self-pollinated by the wind. The fruit has 2 to 18 locules (chambers or sections) (Yeboah, 2011). Tomato varieties are classified as determinate or indeterminate. Determinate or bush types bear a full crop all at once and top off at a specific height. They are preferred by commercial growers who wish to harvest a whole field at one time. Indeterminate varieties develop into vines that, under favorable growing conditions, never top off and continue to produce fruit until cold weather sets in. They are preferred by commercial fresh market growers and home growers who want ripe fruit throughout a growing season (Balaj *et al.,* 2017).

2.3 World Production of Tomato

Tomato is the world's largest vegetable crop after Irish potato and sweet potato (Camargo & Camargo, 2017), but it tops the list of canned vegetables and the global production is to the tune of 1279.93MT/ha. Table 2.1 shows the major tomato producing countries, area, production, productivity and percentage share of world production Arah *et al.* (2015).

Table 2.1: Major tomato producing countries in the world.

Country	Area (000' ha)	Production (000't)	Productivity (t / ha)	% share of world production
Brazil	61	3453	56.61	2.70
China	1305	31626	24.23	24.71
Egypt	195	7600	38.97	5.94
India	535	9362	17.50	7.31
Iran	139	4781	34.40	3.74
Italy	139	7187	51.71	5.62
Mexico	119	2800	23.53	2.19
Spain	72	4810	66.81	3.76
Turkey	260	10050	38.65	7.85
USA	167	11043	66.13	8.62
Others	1624	35281	21.72	27.56
TOTAL	4616	127993	27.73	

Source: Arah *et al.* (2015)

The world trade in tomato consists of an export of 49.50million tones valued at 50802.88M US$ and imports are to the tune of 47.30million tones estimated at 50415.26 US$ (Srinivasan, 2010). Apart from potato, tomato is the second vegetable crop of utmost

importance in the world, producing nearly 164 million tons of fresh tomato fruit which is harvested from 4.7 million hectares (ha) of land globally (Camargo & Camargo, 2017).

Aduhene-Chinbuah (2018) reported tomato production for 144 countries with China leading the world in tomato production both in hectares of harvested production of 1,255,100 hectares and fruit weight production of 30,102,040 Mt. Belgium and the Netherlands are also the other two majors tomato producing countries in terms of yield of fruit per hectare of 4,961,539 km/ha and 4,166,667km/ha respectively (Aduhene-Chinbuah, 2018). Ghana ranks 48th in the production of tomatoes worldwide, producing 366,772 Mt annually (Aduhene-Chinbuah, 2018).

2.4 Tomato Production in Ghana

In Ghana tomato is an important crop forming a major part of the diet of Ghanaians and is one of the commodities in high demand on the market. However, tomato production in Ghana has not reached its potential, in terms of realizing yields comparable to other countries (Robinson & Kolavalli, 2010).

Fresh tomato consumed in Ghana is produced locally however; there is a considerable cross-border trade between Ghana and her neighborhood, especially Burkina Faso for fresh tomatoes while processed forms as puree and pastes are imported from EU, China (Donkoh *et al*., 2013). It is estimated that Ghana produces over 300,000 MT of tomatoes and 90% of the production is consumed locally (Aduhene-Chinbuah, 2018).

Ghana depends largely on regional imports for vegetables during the off season, with imports between 70,000 –80,000 tons of fresh tomatoes from neighboring countries such

as Burkina Faso. It also imports over 78,000 tons of tomato paste and puree per year, of which 12,000 tons is exported after being repackaged (Aduhene-Chinbuah, 2018).

Tomato from 'farm folk' is handled by a number of actors which include the farmers who produce, market queens, middlemen, 'loading boys' (when loading on farm and when offloading at the market centers), driver's/transport operators, the wholesalers and retailers before it reaches the consumer. Over 90,000 farmers are involved in tomato production and more than 300,000 individuals in retail and wholesale areas of the subsector. FAOSTAT, 2016, about 25% of the actors are involved in getting tomato from farm to plate (Robinson & Kolavalli, 2010).

In Ghana, tomato is both a cash and food crop. It is the second most important vegetable consumed (estimated 38% of household budget on vegetables) locally after chilies. It is consumed on its own and used in soup, sauces and salads (Asuming-Brempong *et al.*, 2013). There is a fairly robust market growth that suggests that tomato production is sustainable in the near future, and will continue to deliver good value to the small farm holders and poor households who engage in its production for some time. However, local production has not kept pace with the growth of the market, allowing an influx of fresh tomato imports from neighboring countries (mainly Burkina Faso) and processed tomato paste from Italy, China, etc. to dominate the market (Awo, 2012).

Tomato production in Ghana is highly seasonal depending on the geography of the area, access to water and rainfall patterns (Laube *et al.*, 2012). Within the calendar year, the northern and southern parts of the country produce tomato at different times of the year. From late December through to April/May. Ghana's Upper East and Northern Regions and

Burkina Faso supply almost all the fresh tomato in the country under irrigation (Namara *et al.,* 2011a). Rain-fed production in the south is from March to June, while Brong Ahafo and Ashanti Regions (reflecting bi-modal rainfall patterns) have longer season (Namara *et al.,* 2011b).

Irrigated tomato production is also done in the south namely some part of the Greater Accra, Brong Ahafo and Ashanti Regions. The tomato supply gaps created between December – May is due to Ghana's inability to produce tomato mainly in the rain fed producing areas such as in Brong Ahafo, Ashanti and Greater Accra Regions (Namara *et al.,* 2011b). Tomato is an important ingredient in most foods consumed widely in every household in Ghana (Robert *et al.,* 2014). Major tomato production areas are in the three northern regions, Ashanti, Brong Ahafo and Greater Accra Regions where soils are sandy loamy with pH 6 - 6.5 and a suitable temperature of 20-27°C. Production data from 2000 to 2012 reveals that tomato production dropped gradually between the year 2000 and 2007 (Laube *et al.,* 2012).

In 2012, domestic tomato production constituted about 70% of fresh tomato consumption (200,000 MT) in Ghana revealing a shortfall of about 100,000 MT imported from Burkina Faso from December to May every year. However, production has been on the increase since 2008 reaching 321,000 MT in 2012 (Ganiu, 2019).

Ghana's tomato sector can be described as a low productivity-high price sector. Agronomic practices, yields and costs vary across the country with domestic supply of fresh and processed tomato insufficient to meet the demand of the Ghanaian populace (Ugonna *et al.,* 2015). Varieties grown locally are not preferred by the Ghanaian market

due to their high-water content and a short shelf life (Robinson & Kolavalli, 2010). The major dictators of cost of production are crop protection, inputs and fertilizers, labour and irrigation. Analysis of cost indicates that inputs contribute the most to production cost under irrigation conditions (Cetin & Vardar, 2008).

That notwithstanding, tomato farmers in the north receive the least price compared to farmers in the Brong Ahafo and Greater Accra Regions. Those from Brong Ahafo who mainly produce under rain fed conditions have the lowest cost but the highest price similar to that of Burkina Faso (Robinson & Kolavalli, 2010). The reason is that the North is close to Burkina Faso where quality of fresh tomato is in abundance and cost of procurement is not marginally different at a transport margin of 33% compared to transportation margins between the three northern regions and Brong Ahafo at 87%. Greater Accra has the highest production cost and also commands the highest prices per metric ton (Cetin & Vardar, 2008).

This can be explained by the low cost of transportation for tomatoes grown in the Greater Accra coupled with the perceived freshness and limited damage to the produce by consumers (Melomey *et al.*, 2022). Tomato cultivation under irrigation is predominant in the Upper East, West and Northern Regions, and accounts for about 35% of the total tomato production in Ghana (Romanus *et al.*, 2013). According to Cao (2017), over 20,000 households in Savannah belt cultivate tomatoes with an estimated annual value of harvest and sale of Gh₵0.41 million and Gh₵0.2 million respectively. Farm productivity remains low and this has often led to high cost of inputs and reduced profit margins (Arah *et al.*, 2015). Ghana has the potential to produce 15MT/ha with improved varieties, but productivity is generally low (7.5MT/ha) as compared to Burkina Faso (25MT/ha) due to

partly very low adoption of improved varieties, as well as good agronomic and farm management practices, thus creating a supply gap in the sector (Arah *et al.,* 2015).

Prices of tomatoes between December and May vary with production, thereby affecting incomes of farmers. The bumper harvest in the Upper East is around December and prices are low (Arah *et al.,* 2015). It increases around March when tomato is scarce, but farmers are faced with competition from imports from Burkina Faso. Due to the seasonal and perishable nature of tomatoes, coupled with the lack of storage facilities, farmers are left with no option but to sell at relatively low prices to traders (Romanus *et al.,* 2013). The price differential between the Upper East and the National capital (Accra) is a clear indication: prices in the capital are 10 times higher. Refusal to sell at such low prices will only leave farmers with rotten tomatoes since they have no storage facilities (Awo, 2012).

Exacerbating this challenge is the lack of processing companies to buy and process fresh tomatoes. There is no well-established and reliable tomato supply chain in the northern part of Ghana: southern importers continue to import from neighboring countries to the neglect of the industry in Ghana (Verma *et al.,* 2019). Productivity will improve if these value chain actors (processors, importers and other major buyers) establish supply chain in the Savannah Belt using contract farming or other mechanisms to support varietal and productivity improvement. Investment by these actors coupled with better access to technologies and production resources are critical to upgrade and sustain the tomato industry in the North, and enhance the crop's role as a major source of income for smallholder tomato producing households (Alhassan & Akudugu, 2020).

2.5 Importance of tomato in Global Agriculture

Tomato is one the most important "protective foods" because of its special nutritive value. It is one the versatile vegetables with wide usage in India culinary tradition (Ugonna *et al.*, 2015). Tomatoes are used for soup, salad, pickles ketchup, puree, sauces and in many other ways. Also, tomato has very few competitors in the value addition chain of processing (Tamilnayagan *et al.*, 2017).

Globe or slice tomatoes are also known as round tomatoes and are mostly used in the preparation of dishes and for processing (Yijo *et al.*, 2021). Beefsteak tomatoes are very large and juicy, have thicker skins, shorter shelf life and are kidney-bean shaped, and mostly used for sandwiches and burgers (Shieh *et al.*, 2014). For tomato paste and sauces, plum varieties are the best type as they contain lower water content and high solid contents. Cherry or cocktail tomatoes are used whole and often time used for salads because of their sweet taste; they are characteristically small and round (Geetha & Indhu, 2020). The grape type which is slightly smaller than the plum type was recently discovered and is also used in salads. Pear shaped tomatoes are also sometimes grown. Other relevant types are the Campari, Tomberries, Oxheart, and Marzano (Geetha & Indhu, 2020).

Tomato is one of the most important vegetables and its fruit forms a component of the diet of a lot of people in the world as its total contribution to human nutrition far outweighs other vegetables (Yijo *et al.*, 2021). High content of minerals, vitamins (i.e. A and C), antioxidants (i.e. lycopene, beta-carotene, flavonoid, phenolic acid), folate, potassium, oxalic acids (i.e. ascorbic, citric, malic, niacin and fumeric) and certain types of hormones precursors are found in tomatoes which are vital to the health of human (Aduhene-Chinbuah, 2018).

A number of diseases (i.e. type II diabetes, 80% of cardiovascular diseases, neurodegenerative diseases and certain types of cancers are reported to be managed with these phytochemicals and organic acids which are obtained from tomato (Ali *et al.*, 2020). Tomato can also protect the skin from skin diseases and sun burns (Zaid *et al.*, 2022).

2.6 Conditions for Tomato Production

2.6.1. Moisture Requirement

Soil moisture requirements differ with the crop and stage of the crop development; its availability varies with the amount of water in the soil and the type of soil (Constantin *et al.*, 2015). Watering plants merits a considerable attention in order to supply the plants with the appropriate amount of this vital nutrient. Water is vital for plant growth and development. Water deficit stress, permanent or temporary, limits the growth and the distribution of natural vegetation and the performance of cultivated plants more than any other environmental factors do (Cassaniti *et al.*, 2012).

Low water availability can also cause physical stress in plants. Stomata are plant cells that control movement of water, carbon dioxide, and oxygen into and out of the plant. During low moisture stress, stomata close to conserve moisture (Karkanis *et al.*, 2011). Moisture is important for growth and survival of plants and how much water to apply depends on many factors including soil type, soil properties, plant species and climatic conditions (Deng *et al.*, 2016). Plants will not thrive well and provide good colour if they are under moisture stress. Irrigation should take into consideration the relationship between soil porosity and storage abilities and the plant water use. Also, moisture conservation practices such as mulching (black/ clear polythene) are critical in deciding irrigation frequency (Deng *et al.*, 2016).

Adequate soil moisture during the Pre -harvest period is essential for the maintenance of post-harvest quality (Deng *et al.,* 2016). According to Lobos *et al.* (2016), water stress during the growing season can affect the size of the harvested plant organ, and lead to soft or dehydrated fruit that is more prone to damage and decay during storage. On the other hand, vegetables experiencing excess of water during the growing season can show a dilution of soluble solids and acids, affecting taste and nutritional quality. A significant impact of globalization on horticulture has been an increasing demand for quality improvement and the wider adoption of quality standards for fruit, vegetable and salad commodities (Mallikarjun *et al*., 2021).

The type of irrigation used in tomato fields depends on the water resources in a growing area. In some regions of Florida, where water is plentiful, furrow or seepage irrigation is used. In California, where water is scarce, drip irrigation is used exclusively because of the efficient use of water (Hussain *et al*., 2020). Regardless of region, overhead sprinklers are routinely used to help establish new tomato transplants. Commercial growers use chemical fertilizers or properly composted organic materials to provide nutrients to growing plants. Fertilizers are applied before seedlings are transplanted, side placing in furrow irrigation systems, or applied through drip irrigation (Abrahamian *et al.*, 2021). The term “chemigation” is the injection of any chemical such as nitrogen, phosphorus, or a pesticide into irrigation water and applied to the land using the irrigation system (Carrow *et al.*, 2012).

2.6.2 Soil Type

Tomatoes grow best in well drained soils that are well supplied with organic matter. Sandy soils are suitable for early production, loam and clay loam soils are suitable for later production (Okiror *et al.,* 2017). Tomatoes grow well in a variety of soil textures, but commercial growers tend to prefer well drained sandy loam soil with high level of organic matter contents as best suited for tomato production. Soils with high acidity are not suitable for tomato cultivation. 3 to 4g per suitable lime can be applied in the field in an interval of three years to reduce the level of acidity to considerable limits (Usman *et al*., 2016). There is a need to go for soil testing at the beginning of the crop season.

Sandy soils drain better and warm up more readily than denser soils. Denser soils like loam and clay loam may also be used as long as the fields are carefully irrigated and well drained. Universally, all soil is prepared prior to planting using a variety of special equipment to improve the overall quality of the soil by breaking up clods and adding amendments (Schoonover & Crim, 2015).

2.7 Summary of major pests of tomato

The major pests of tomato include; cutworm, flea beetles, tomato fruit worm, wireworm just to mention a few (Hillock & Rebek, 2013).

2.8 Summary of major diseases of tomato

Some of the common diseases of tomato include; damping off, sclerotinia, Septoria leaf spot, early blight, late blight, anthracnose and so on (Cawoy *et al*., 2011).

2.9 Pruning

A sucker is new growth that occurs between the axil of the leaf and stem. There will usually be one sucker at the axil of every leaf. If suckers are allowed to grow, they will also produce suckers. Suckers produce both foliage and fruit. If not removed, they will produce more foliage than the root system can adequately support and provide additional material to harbor disease and insect organisms (Flint, 2018). If the suckers become much longer, they become difficult to remove without leaving a wound on the stem. Wounds become points of entry for fungal organisms, which are major problems as greenhouse humidity increases. Usually, a plant can be pruned to a two-stem system, although soilless systems are normally pruned to one stem. One-stem plants are desirable when close spacing are used, but are less necessary with wider spacing (Askari-Khorasgani & Pessarakli, 2020).

2.10 Irrigation Practices

Tomatoes grown in soil culture should be irrigated so that water is delivered to the base of the plant rather than through overhead sprinkler systems. This keeps water off the foliage and reduces the potential for fungal diseases such as botrytis or leaf mold, which can devastate crop yields (Stewart-Wade, 2011). Greenhouse tomato growers have improved their yield per plant by shifting from sprinkler to trickle irrigation. Water application at the base of the plant in soil systems also reduces greenhouse humidity and weed growth between rows. Systems can be designed with a minimum of one plastic line per row; however, some growers use a line on each side of the row (Stewart-Wade, 2011).

The components of a drip irrigation system include a fertilizer injector, filtration units, pressure regulators, drip tape, supply lines and various connectors, seals and plugs or clamps (Waseem, 2020). Hydroponic Systems, where water and fertilizer are applied

simultaneously to the roots through the plumbing system installed in the growing trays, troughs or bags (Baras, 2018).

2.11 Harvesting and Handling

Fruits must be picked at the ripe, pink or mature-green stage depending on its use and distance to market. At about 21℃ pink fruits ripen in 1 to 2 days and mature-green fruits in 4 to 5 days (Sikorska-Zimny *et al.,* 2019). Exposure of green fruit to ethylene supplied as a gas to harvested fruit, or as a field spray of ethephon, accelerates ripening. Prolonged exposure to temperatures above 30℃ can inhibit red pigment formation (Dhall, 2013). Ethephon is used for field ripening of processing tomatoes before harvesting (Jędrszczyk *et al.,* 2019).

2.12 Storage and Conditioning

Mature-green tomatoes should be stored at 13℃-21 ℃. Optimum temperatures for ripening are between 18℃ to 21 ℃, while 14℃ to 16℃ is most desirable for slowing ripening without increasing decay (Dhakal & Baek, 2014). Firm ripe fruit can be held as low as 7℃ to 10℃ (pink fruits are stored at intermediate temperatures, 10℃ to 15℃). Relative humidity in all cases should be 90 to 95% (Sugri *et al.,* 2013). Mature green fruit can be held 2 to 6 weeks while ripe fruit can only be held one week in conventional storage (Rao & Shivashankara, 2015). Controlled atmosphere storage may be used to delay ripening and extend storage life. Botrytis and Alternaria rots may be a problem, especially if fruits have been chilled in the field or in storage (Thompson *et al.,* 2018).

2.13 Challenges Associated with Tomato production in Ghana

Tomato yields in Ghana (7.5 tons/ha) does not reach its potential (15 tons/ha) and yet other neighbouring countries such as Burkina Faso produce about 12.5 tons/ha leading to Ghana importing from Burkina Faso to augment the short fall in production (Aduhene-Chinbuah, 2018). The low yield in tomato production is due to a number of challenges (Aduhene-Chinbuah, 2018).

i. High post-harvest losses during the peak production season due to lack of processing and storage facilities.

ii. Unavailability of registered Agro-chemical shops where farmers can obtain trusted, selected and viable seeds for their commercial production. Due to this menace, most tomato farmers in Ghana obtain their seeds from their personal stored seeds, some also obtain seeds from the local markets, and others obtain seeds from friends and family. These informal seed sources are usually not of high quality in terms of viability and hence affect high production. Farmers must be encouraged to purchase high quality seeds from certified seed companies and government must subsidize the cost of high-quality seeds to allow farmers to have access to them.

iii. High cost of agricultural inputs (i.e. fertilizers, pesticides, seeds, water charges, tractor services, etc.), high rent charges.

iv. Traditional land tenure system. No or difficulty of obtaining land for expansion, no places to relocate nurseries, no storage facilities.

v. Difficulties in accessing credit, lack of capital to invest in the production, among others are some other challenges farmers face (Clottey *et al.*, 2019).

vi. High interest rate on credit facilities

vii. Pests and diseases problems (Ugonna *et al.*, 2015).

2.14 Features of Medium

Tala *et al.* (2020) pointed out that the quality of the substrate is one of the important factors to consider when selecting a substrate for cultivation. The substrate chosen should be able to enhance shoot and root growth (Kazemi & Mohorko, 2017). To be able to determine the quality of the substrate the chemical and physical properties must be evaluated. Since, not one substrate provides the crop all that is needed, when the chemical and physical characteristics are checked, the shortfall can be supplemented by the growers (Maucieri *et al.*, 2019).

2.14.1 Physical Features of the Medium

Soilless media physical component is made up of four parts, which are 20-30% solids, 10-25% available water, 20-30% airspaces and 15-45% residual water (Aduhene-Chinbuah, 2018).

Hill *et al.* (2019) noted that of all the parts of the soilless media, the most relevant is the air spaces and available water which depends on the shape and particle size of the media. Bunt (2012) reported that when the media is dense with airspaces of less than 1%, the aeration of the roots become a problem for plant growth. Bunt (2012) further observed that the plant can take up more water than is available in the medium, but would need to use up more energy to achieve this. Coarse particles usually have large air pores of about 0.5mm or larger, which facilitates proper aeration in the medium. However, when the media is of medium texture, it has an air pore of 0.1-0.5mm which also facilitates water availability (Haynes *et al.*, 2021).

Alghamdi *et al.* (2020) opines that when fine particles have air pores of about 0.1mm then it will be able to hold some water, but this will not be available enough for the plant use. In selection of substrate there should be a fine mix of both 0.75cm coarse and 0.5cm medium sized particle, with little fine particle (i.e. 5% of the total substrate) (Schwarz, 2012).

2.14.2 Chemical characteristics of growth Media

The pH, Electrical conductivity (EC) and CEC (Cation Exchange Capacity) are the chemical characteristics mostly determined for medium (Schwarz r *et al.*, 2012). The salt content of water as a result of flow of electrical current is what is referred to as Electrical Conductivity (EC) (Liu *et al.,* 2017). According to Valdés *et al.* (2015) the salt content of the substrate is what determines the electrical conductivity. The amount of ions from fertilizer salt that dissolves in substrate solution is Electrical Conductivity.

Thus, an increase in the amount of fertilizer applied causes high levels of salt in the substrate or soil. When the EC of the soil or substrate is high it decreases the supply of water to the plant root and can cause some problems to the plant (Hussain *et al.,* 2014).

2.15 Cocopeat

This is the most commonly used medium in greenhouse production worldwide. Cocopeat is a product from coconut husk. Composting the cocopeat must be rehydrated before it can be used as a growing medium. It is naturally anti-fungal, making it an excellent choice to start seed (Xego, 2017). Cocopeat is so environmentally friendly that it is reusable. In a comparison of cocopeat versus soil, the peat retains much more water and releases it slowly to plant roots (Al Marzooqi, 2020). The coco fiber is the brick type and mixed with poultry

droppings and soil to create air pockets that bring oxygen to plant roots. It must always be kept moist and checked frequently to ensure plant water requirement is met (Gruda, 2019).

Cocopeat has several benefits among them are; it is organic in nature, its raw material is readily available, it is convenient to bag and transport due to its light weight, beneficial for both the plants and soil microorganism, improves soil fertility, increases soil porosity, increasing aeration which is beneficial to the plants, it also has long lasting biological effect in soil, etc. (Gruda, 2019).

Until recently coconut coir was dumped indiscriminately as it was considered as a waste product (Ekpenyong *et al.*, 2022). It is now prepared and used as medium for growing of crops in greenhouse after sterilization. Since cocopeat is organic and biodegradable in nature it is environmentally friendly and gives the needed yield that would have been obtained from rock wool and peat moss. The fact that it is obtained from renewable resource is an added advantage (Atzori *et al.*, 2021).

Cocopeat is slow decomposing hence as a soil conditioner stays in the soil for over 3 years before totally decomposing. It can also be used in the greenhouse as a soilless medium for more than 3years (Shukla *et al.*, 2021). Cocopeat is able to retain moisture which allows for plant nutrients in solution to remain in the soil at the root zone and this in turn facilitates root formation and going forward, high crop yield (Gruda, 2019).

Also, its high-water holding capacity facilitates lowering of temperatures and crop load demand still ensuring that air supply is enough. Cocopeat is also very high in organic

compound, micro and macronutrients and this helps in the resistance of pest and disease and also helps in root growth and development (Aduhene-Chinbuah, 2018).

Cocopeat is used in container growth, seed starting mixes and also in bedding plants. It has a pH of 5.0 -6.8, which is adequate for alkaline garden soil and is consequently resistant to bacterial and fungal growth. It holds about 8 to 9 times its weight in water (Daria *et al.*, 2020). The nutrients are also stored and released to the plants periodically for a long time and also have high oxygenation properties which are needed for healthy root development of crop (Jones Jr, 2012).

2.16 Effects of Container sizes on plant growth and development.

Container sizes affect root development thereby change the morphology and physiological response of plants depending on the size of the media vessel used and this has been reported in many studies (Alameda & Villar, 2012). It is necessary to use container sizes that will give best quality performance and high yield of crops. The yield and performance results obtained from research done on these containers on tomatoes and other plants vary (Del Borghi *et al*., 2014).

There is a difference in morphology of roots of plants grown in open field and those grown in containers in the greenhouse (Judd *et al*., 2015). Judd *et al*. (2015) again observed that tomatoes grown in containers had lost most of its primary roots in favour of lateral ones. The reverse was true for those grown in open field.

The container size used for production affects the rate of root restrictions which will then have an effect on the accumulation and partitioning of biomass, root and shoot

development, leaf chlorophyll content, photosynthetic rates, uptake of nutrients, the relationship between the crops and water, respiration rate, flowering, yield and yield component of the crops (Zakaria *et al.,* 2020). In contrast, Cordovez *et al.* (2017) observed that root restriction caused by planting in small containers accelerated the flowering process and caused early harvest. Sibomana *et al.* (2013) saw an increase in yields of tomato that was grown in smaller containers. Cost of production of tomatoes is reduced when small containers are used (Huang *et al.,* 2019).

With small containers the number of plants produced increases and reduces the space needed for production of tomatoes (Zakaria *et al.,* 2020), which is mostly adopted by commercial farmers. Daria *et al.,* (2020) explained that larger pots cause drying of substrates at the surface and middle portion as a result of leaching. This makes nutrients and water unavailable to plants. In smaller pots water and nutrients are readily available to the plants.

2.17 Greenhouse Technology

Greenhouse technology is the system where crops are grown in an enclosed structure with careful visitation and supervision. Agro-climatic conditions favorable for plant growth is created in the enclosed space and the amount of solar radiation needed for plant growth is regulated (Moe, 2015). Extensive studies conducted on field and greenhouse tomatoes have shown that the greenhouses produce higher yields and quality tomatoes than the open field plants (Zarei *et al.,* 2019). This has been attributed to the controlled environment within the greenhouses which provides optimum growing conditions for the tomato crops (Shamshiri *et al.,* 2018).

Based on crop specification, greenhouses may permit the regulation of key environmental factors such as amount of light and shade, temperature, fertilizer application, irrigation and atmospheric humidity, which are the major challenges of the open field cultivation (Rodríguez *et al.,* 2015). Greenhouses also facilitate year-round production allowing for crop production even under adverse weather conditions (Zarei *et al.,* 2019).

In producing crops in the greenhouse, a number of cultural inputs and factors are involved. These include physical and chemical properties of the root media, irrigation frequency, crop type, container type, as well as size and climatic conditions (Savvas & Gruda, 2018). Varying substrates components have different effects on crop production, hence, choice of the growing medium to use is critical to achieving maximum crop production. As a result of the somewhat shallow depth and restricted volume of container, there is also the need to amend growing media to provide the suitable physical and chemical properties essential for plant growth (Gruda, 2019).

Domestication of plants is one of the greatest achievements of man. This allowed mankind to cultivate types of crops they wish for in larger quantities. Now human beings have chosen to cultivate crops under protected environment to prevent the effect of abiotic and biotic stress (Goudie, 2018). This seeks to ensure that maximum production of crops can be grown on a small piece of land and all year-round production is also assured. This ensures food security and reduces poverty (Adeyeye, 2017).

A greenhouse is usually a framed structure. However, in some cases it can be an inflated structure. In both cases it is covered by a translucent or transparent material that is able to regulate environment and prevent the influence of external climatic conditions (Sandak *et*

al., 2019). The size of the greenhouse structure allows for all cultural practices which would otherwise be performed on the field to take place also in the greenhouse (Rodríguez *et al*., 2015).

Many of the greenhouses were part of the 160 greenhouses that were built in Ghana in 2015 by West African Productivity Programme sponsored by World Bank (World Bank Group, 2014). It is therefore very clear that, in greenhouse production a number of factors (i.e. good design, inputs used, medium, container types and crop management practices) need to be considered to be able to obtain consistent high yields (Smith *et al*., 2019).

World Bank has again in 2018 donated 2 million dollars to WAPP under the direct Supervision of WECARD (West and Central African Council for Agricultural Research and Development) for construction of 260 greenhouses for tomato, cucumber and sweet pepper. It is believed that this will provide employment for over 700,000 people (World Bank Group, 2014).

The most common crop grown in the greenhouse in Ghana is tomatoes. This is because the demand for tomatoes is high throughout the year and therefore higher prices can be obtained in the dry season (Melomey *et al.*, 2022). Also, farmers are able to prolong their production up to six months with the indeterminate varieties (Stone, C. A. (2015). The Council for Scientific and Industrial Research reports that Ghana can be Africa's leading tomato producer if greenhouse farming is expanded (Silva *et al.*, 2017).

2.17.1 *Types of materials for Greenhouses*

Greenhouses for tomato production may be constructed using these three basic types of material: (1) Glass; (2) Soft, pliable plastic films; or (3) Rigid plastic or fiberglass (Teitel *et al.*, 2017). Tomatoes can be grown equally well in houses covered with any of these materials, although management practices may vary somewhat. For example, plastic houses are usually more nearly airtight than glass houses; therefore, ventilation may be more critical. The relative cost of the materials, the prevailing environmental conditions at the time, the anticipated life expectancy of the structure, and the personal preferences of the farmer will be a determinant factor in the choice of the type of greenhouse to be constructed (Khoshnevisan *et al.*, 2019).

2.17.2 *Greenhouse made with Glass*

Glass-covered greenhouses are the most durable of all types. They are less subject to damage from high winds and heavy snow loads than most plastic greenhouses. Glass greenhouses are considered permanent structures with permanent walks, heating systems, and other internal features (Syed & Hachem, 2019; Yano & Cossu, 2019). Since they are permanent, they can be insured. In some cases, growing tomatoes in a glass house may require less management than growing them in plastic greenhouses. However, it is high capital intensive which is the fundamental disadvantage of a glass greenhouse (Syed & Hachem, 2019).

Also, as permanent structures, they usually have a higher tax assessment than plastic greenhouses. Another disadvantage of glass house is that they are subject to damage from hail or rocks (Syed & Hachem, 2019). In areas where hailstorms are common, glass houses are not recommended. Glass greenhouses for tomato production are usually constructed with truss-supported, even-spanned roofs (Yano & Cossu, 2019)

2.17.3 Greenhouse made with Plastic Film

Greenhouses covered with plastic film can generally be constructed for one-third or less of the cost of a glass greenhouse. This makes plastic greenhouses popular with farmers who are just getting established and do not have the resources necessary to construct a conventional glass house (Pack & Mehta, 2012). Plastic greenhouses usually have wooden or metal pipe frames. They may be of any of several designs. They are usually built as temporary structures, designed to last only a few years, and therefore maintenance costs are high (Pack & Mehta, 2012). Usually, plastic greenhouses have a lower tax assessment than glass greenhouses, because they are only temporary structures (Khoshnevisan *et al.,* 2019).

Plastic greenhouses may be of several different designs, including A-frame, scissors- truss, truss-rafters, center-post, rigid-frame, gothic arch, Quonset, panel, ridge-and-furrow, and air-supported houses (Maraveas & Tsavdaridis, 2020). Whichever design is used, consideration should be given to maximum light penetration, easy ventilation, and adequate heat for photosynthetic activities (El-Gayar *et al.,* 2018).

On the inside, plastic greenhouses for tomato production are quite similar to glass houses. The type of heating system best suited for a greenhouse depends on the size and design of the house and the climate of the area where the greenhouse is located. The heating system must be able to maintain a minimum temperature of 27°C on the coldest nights and must release no toxic gases into the greenhouse (El-Gayar *et al.,* 2018).

2.17.4 Rigid Vinyl or Fiberglass Greenhouse

Greenhouses covered with rigid panels of polyvinyl chloride (PVC) or fiber glass are satisfactory for tomato production. The durability of these materials may range from 2 to 20 years, depending on the quality (McCartney & Lefsrud, 2018). PVC panels and cheaper grades of fiberglass may discolor so badly that they no longer allow satisfactory plant growth. PVC is also quite susceptible to hail damage and should not be used in areas where hailstorms are common source (Liu *et al.*, 2021; Lucy & Petty, 2021). A serious peril of fiberglass is its susceptibility to fire. The rigid materials are usually used on permanent structures, and may be as expensive to build as a glass greenhouse (Shogren *et al.*, 2019). The frame, heating, ventilation, and watering for such a house are similar to those discussed for glass greenhouses (Shogren *et al.*, 2019).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Location of the Project and Time of Experiment

The experiment was carried out at the Multi-Purpose Nursery of the University of Education Winneba, Mampong –Ashanti. Mampong-Ashanti lies at the transitional zone between the forest and northern savanna zones of Ghana and lies at 57.6km North of Kumasi on latitude 07ºC 04N and longitude 01ºC 024W of the equator and it is 457.5m above sea level (Metro Dept., 2008).

3.2 Climate

Mampong has a bimodal rainfall pattern with annual mean rainfall between 1094.4mm and 1200mm and the monthly mean rainfall of about 91.2mm. The major rainy season starts from March to July whereas the minor rainy season occurs from September to November (Metro Dept., 2008). Mampong has a mean daily temperature of about 30.5º C and night temperature of 26º C. The experiment lasted for twelve weeks (84 days) and was commenced on the 23rd of July to 23rd day of August before transplanting was done and ended on the 18th of November, 2019.

3.3 Cocopeat

The cocopeat, most appropriately called coconut coir, is an organic matter used as a growth medium for propagation. This was made from the pith inside a coconut husk by beating and separated into coconut fiber.

3.4 Planting Materials, Acquisition of Materials and Sources

3.4.1 Planting Materials and Sources

(a) Seeds.

Tomato seeds were bought from Nirit Seeds LTD in Accra Ghana. The variety of tomato sown was TYTANIUM F1

(b) Buckets

A total of ninety (90) buckets of 12L capacity were bought from Mampong market on the 21st of August, 2019 for the purposes of this project as pots. The buckets were perforated at the bottom on the next day for aeration and draining of excess water. The average number of holes perforated on each bucket is five (5) at 2.5cm wide.

(c) Polythene Sheets

White polythene sheets were also bought from Mampong market on the same day. These sheets were spread to cover the soil surface to prevent soil borne diseases from entering the pots.

(d) Funnel and Voltic Bottles

Two funnels were bought from the market to be used as component of improvised rain gauge in the open field to determine the water difference when it rains. Three Voltic bottles of size 12L capacity were also collected together with the funnel to use as improvised rain gauges.

3.5 Experimental Design and Treatment

3.5.1 Layout of Experimental Plots

Two experimental lines consisting of ninety pots each were studied under two environments (i.e. green house and open field environments). Calibration of water drip

lines were done in both environments on the 19th August, 2019 at 4: 38pm using cut Voltic water bottles of 1L capacity in each environment.

3.6 Cultural Practices

3.6.1 Land Preparation

The land for the project was cleared on the 19th day of August, 2019 with cutlasses and hoes. The land was further levelled on the next day using pick axe and rake.

3.6.2 Nursery

The seeds were nursed at the Multi-Purpose Nursery of the University of Education, Winneba, Mampong-Ashanti. in the seedbed at the nursery site on the 23rd July, 2019. The seeds nursed were one seed per hill. By the eighth day after nursing, 95% of the seeds had germinated.

3.6.3 Transplanting of Seedlings

One seedling or one tomato plant was put in each of the ninety plastic pots as the planting number per pot. The pH of the cocopeat was around 5.5-6.8. The tomato seedlings were transplanted on the 23rd of August, 2019 in the green house and in the open field. The cocopeat was sterilized and mixed with poultry droppings before the pots were filled and seedlings transplanted later.

3.6.4 Weed Control

Weeds are a big nuisance as they compete with crops for nutrients, space and water in the soil and can also harbour pests and diseases that cause harm to tomatoes. Weed control was manually done using cutlasses, hoes, hands and in some cases herbicides. Specifically, hand picking was carried out in the pots as cutlass, hoes and herbicides were used in the

surrounding environment. The first weeding was done on the 5th September, 2019 and *Cyperus* spp were the common weeds and, subsequent weeding was carried out in both environments till the project was over.

3.6.5 Fertilizer Application

Fertigation chemicals used for this project were Calcium nitrate plus Mono ammonium phosphate mixed and potassium nitrate plus Magnesium sulphate. Potassium nitrate,4kg to magnesium sulphate of 3.2kg per 1000litres of water and 3.2kg of calcium nitrate to mono ammonium phosphate of 0.75kg per 1000litres of water respectively. Fertilizer was applied in the morning and afternoon during the vegetative growth and morning, afternoon and evening during fruiting stage for every 20munites each time.

3.6.6 Watering

The first watering was done on the 23rd August, 2019 immediately the seedlings were transplanted in both the green house and the open field. Watering is done every morning and evening 166ml of water was delivered through drip lines for twenty (20) minutes per pot.

3.6.7 Pest and Disease Control

Pests and diseases were controlled using Chemaprid 88EC (20ml/8 litres of water) and D-Lion® Fungi 2020 (Copper hydroxide 77% WP). Subsequent fumigation was carried out. Some of the common insect pests of tomato that were found: caterpillar, flea beetles, tomato fruit worm etc. On the other hand, the common diseases of tomato included; Leaf blight, Septoria Leaf Spot, Anthracnose, Leaf curl, just to mention a few. This was carried out for the period of two weeks.

3.7 Data Collection

3.7.1 Plant Height

The height of each experimental plant in both environments was taken every week using a meter rule to measure from the base of the stem to the apical leaf for five weeks. The average mean height of each experimental plant in each pot was taken with respect to treatments. A sampling of fifteen plants from each treatment was selected from the middle of each line.

3.7.2 Number of Branches

On 11th September, counting of number of branches for the tagged plants commenced during the morning on weekly basis and recorded for both environments. The average mean for each environment was calculated and recorded.

3.7.3 Stem Girth

Stem girth was measured and recorded using a vennier caliper for the thirty experimental tomato plants from 5cm the ground level for five times during the vegetative period. The thicker the stem girth the stronger the plant stays firm without logging hence produce bigger, clean and unrotting fruits and therefore high economic gain.

3.7.4 Number of Flowers

Starting from 11th September, 2019, counting of number of flowers of all the thirty experimental tomato plants commenced manually and recorded five times. (i.e. every ten (10) days) by hand. Significantly, the number of flowers formed on each plant, determine the number of fruits produced. The higher the number of fruits the more profitable it turns out to the farmer.

3.7.5 Number of Fruits

The total number of fruits harvested from the ninety pots was counted and the average for each determined. This started on the 10th day of November and repeated at weekly intervals. When more fruits are produced, it turns out to bring economic benefits to the farmer.

3.7.6 Vertical Fruit Length

The length of all fresh fruits harvested from each environment was measured with a veneer caliper and the average for fresh fruit for each environment was determined.

3.7.7 Fruit Weight

The weight of each experimental fruit in each environment was taken using a weighing scale. The average mean weight of each experimental fruit on each environment was taken with respect to the environment.

3.7.8 Vertical Fruit Diameter

The diameter of each experimental fruit on each environment was taken using the Vernier caliper. The average diameter of each experimental fruit on each environment was taken with respect to the environments. This was done every week.

3.7.9 Harvesting

The first harvesting was done on the 10th day of November, 2019 by hand picking and was followed by subsequent harvesting for two times. (i.e. every seven (7) days interval).

3.8 Data Collection

Data collection started four weeks after transplanting. Growth measurement was taken once in every seven days for five weeks while yield measurement was taken at the time of harvest.

3.9 Analysis of Data

Data was analyzed with the Student T-Test, Microsoft excel, Gen-Stat and mean separation carried out using the least significant difference (LSD) test.

CHAPTER FOUR

4.0 RESULTS

4.1 Effects of Greenhouse Technology on Plant Height (cm)

Figure 4.1 shows the effect of greenhouse technology on tomato plants height. The T-test results revealed a significant ($P<0.05$) differences in plant height among tomatoes grown under greenhouse and open field technology across the period of study (Figure 4.1). The taller ($P<0.05$) plants at 1 week were observed from the open field while the green house technology recorded shorter ($P<0.05$) plants. Again, at 3, 5, 7, and 9 weeks after planting, tomato plants grown under in the open field recorded taller plants as compared to the tomato plants grown under greenhouse technology.

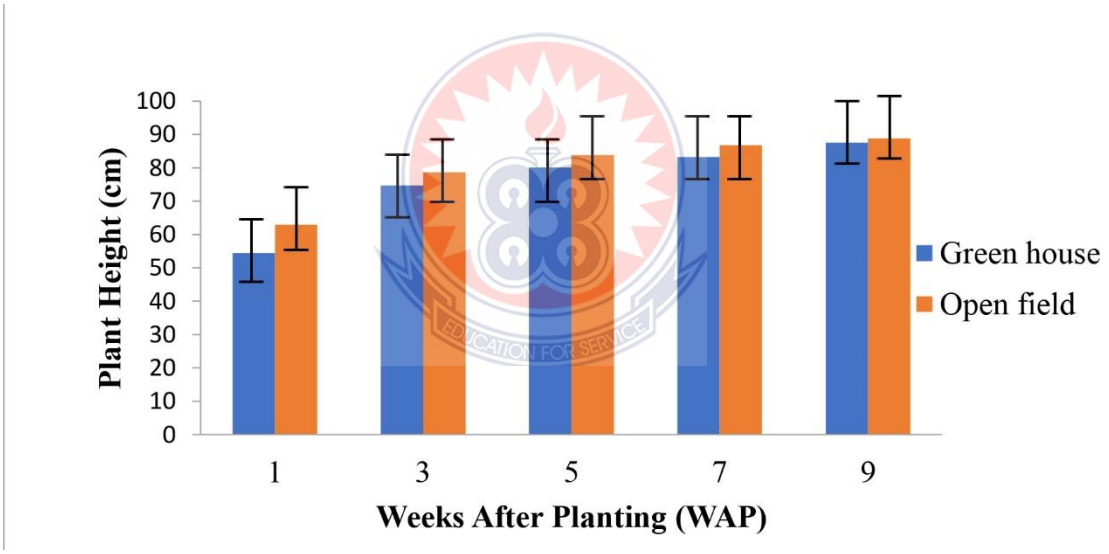

Figure 4.1: Effects of greenhouse technology on plant height (cm) of tomato1

4.2 Effects of Greenhouse Technology on Number of Branches

Figure 4.2 shows the effect of greenhouse technology on the number of branches produced over the period of study. Results from the study revealed that number of branches was significantly ($P<0.05$) influence by the greenhouse and open field technologies. Number of branches produced at 1, 3, 5, 7 and 9 weeks after planting were higher ($P<0.05$) among

tomatoes plants grown in the open field and lower (P<0.05) among tomatoes plants grown under the green house technology (Figure 4.2).

4.3 Effects of Greenhouse Technology on Stem Girth (cm)

Figure 4.3 shows the effect of greenhouse technology on tomato stem girth. Results from the study shown a significant (P<0.05) differences among tomatoes stem girth grown under greenhouse and open field technology across the period of study. Tomatoes grown in the open field recorded the higher stem girth in comparison with tomato plants grown under the green house technology at 1, 3, 5 and 7 weeks after planting. However, at 9 weeks after planting, tomato plants grown under the green house technology recorded higher stem girth in comparison with tomatoes grown in the open field.

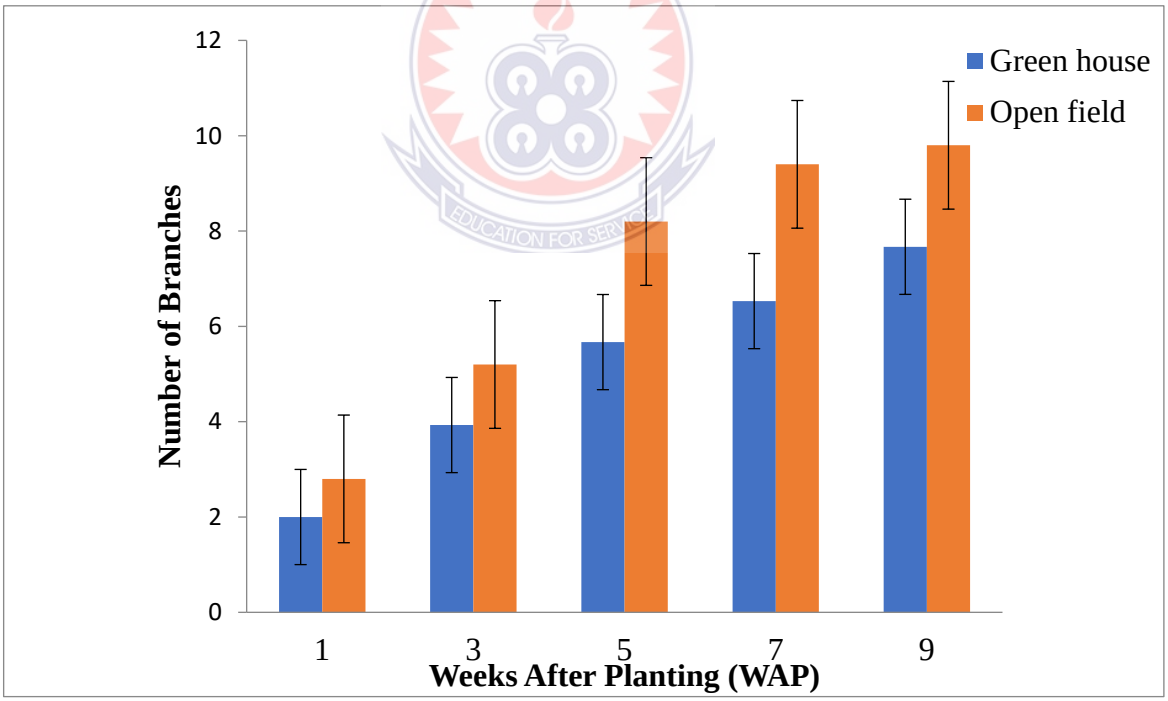

Figure 4.2: Effects of greenhouse technology on number of branches of tomato2

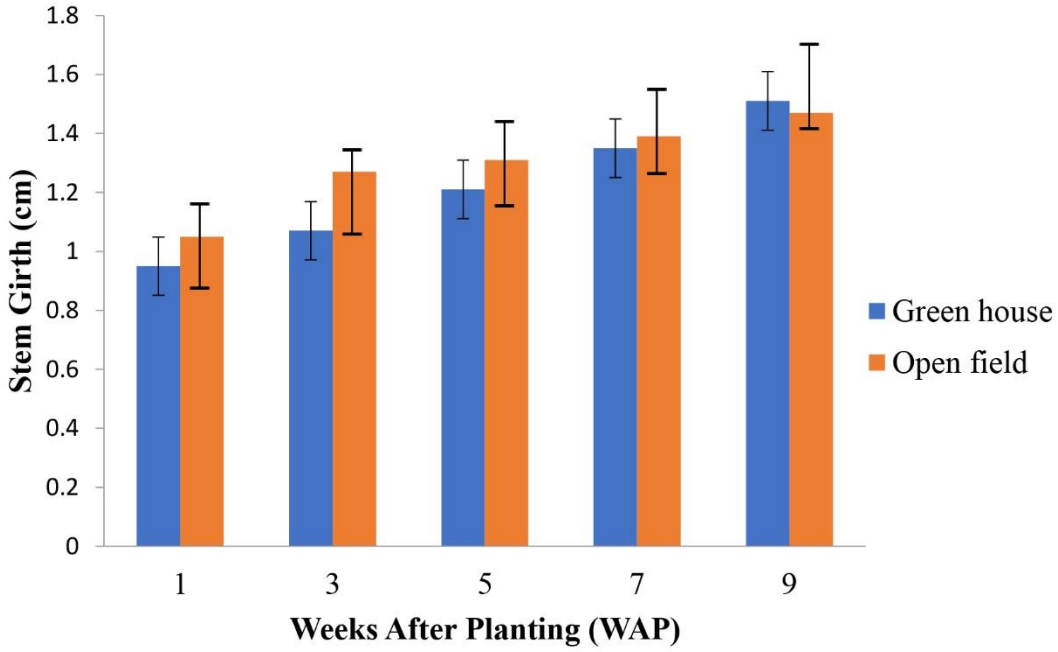

Figure 4.3: Effects of greenhouse technology on stem girth (cm) 3

4.4 Effects of greenhouse technology on number of flowers

Figure 4.4 shows the effect of greenhouse technology on number of flowers produced by the tomatoes plant. Results from the study show that, greenhouse and open field technology had significant ($P<0.05$) effect on the number of flowers produced by the plants. Tomato plants grown under greenhouse technology recorded the higher number of flowers in comparison with the open field at 1, 3, 5, 7 and 9 weeks after planting.

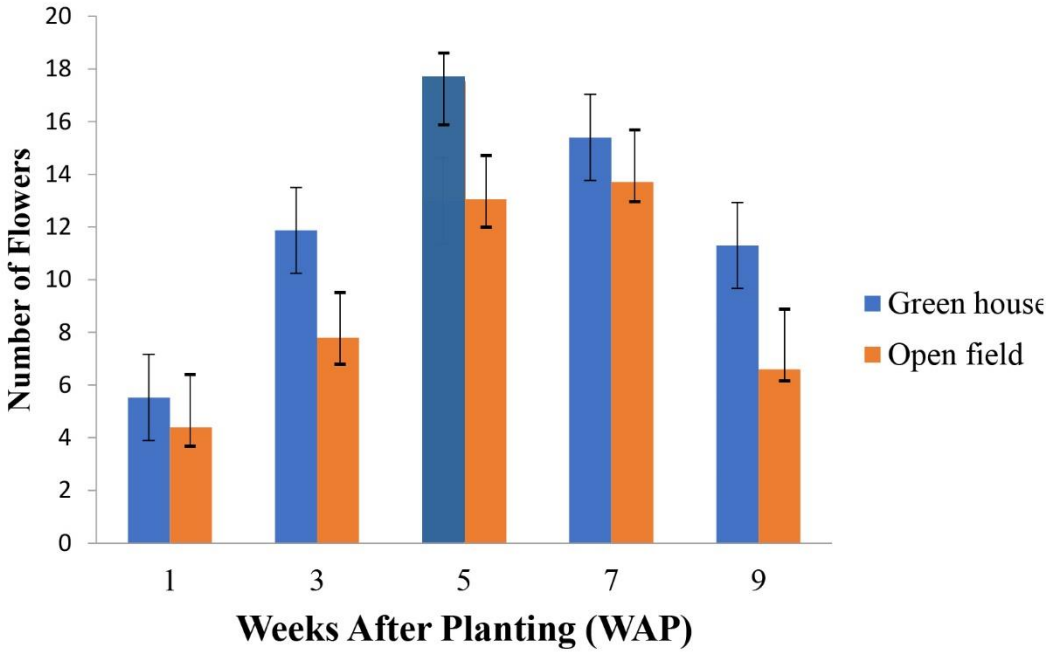

Figure 4.4: Effects of greenhouse technology on number of flowers4

4.5 Effects of greenhouse technology on number of fruits harvested

Figure 4.5 shows the effect of greenhouse technology on the number of fruits harvested. Results from the study show that, greenhouse and open field technology had significant ($P<0.05$) effect on number of fruits harvested across the days of harvesting. The T-test results revealed that, at 1, 2 and 3 days of harvesting, tomato plants grown under the greenhouse technology recorded higher ($P<0.05$) number of fruits in comparison with tomatoes plants grown in the open field. (Figure 4.4).

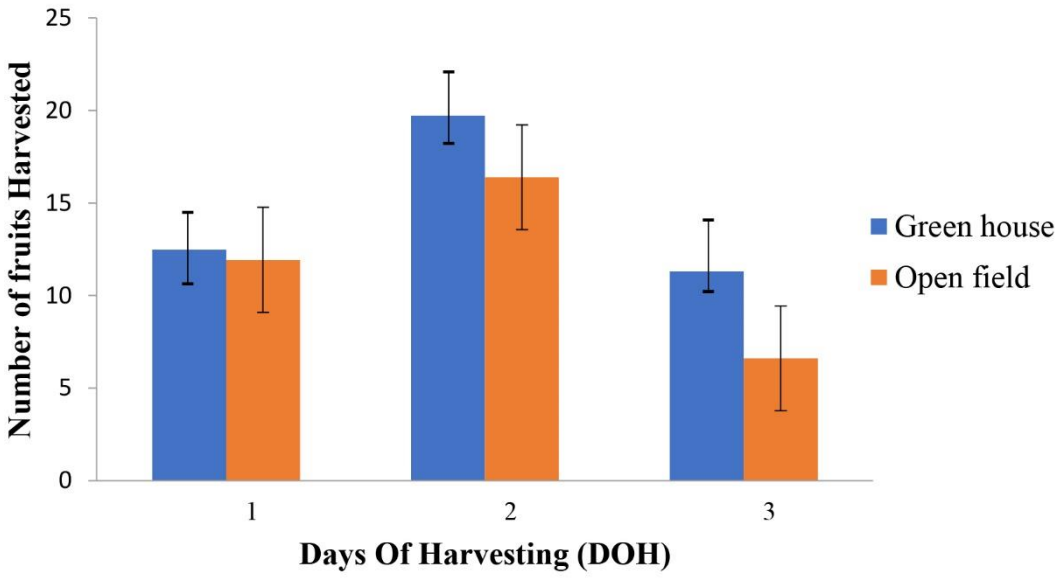

Figure 4.5: Effects of greenhouse technology on number of fruits harvested5

4.6 Effects of greenhouse technology on harvested fruits weight (g)

Figure 4.6 shows the effect of greenhouse technology on harvested fruit weight. Results from the study show that, greenhouse and open field technology had significant ($P<0.05$) effect on harvested fruit weight across the days of harvesting. Figure 4.6 shows that, at 1, 2 and 3 days of harvesting, tomato plants grown under the green house technology recorded higher ($P<0.05$) harvested fruit weight in comparison with tomatoes plants grown in the open field.

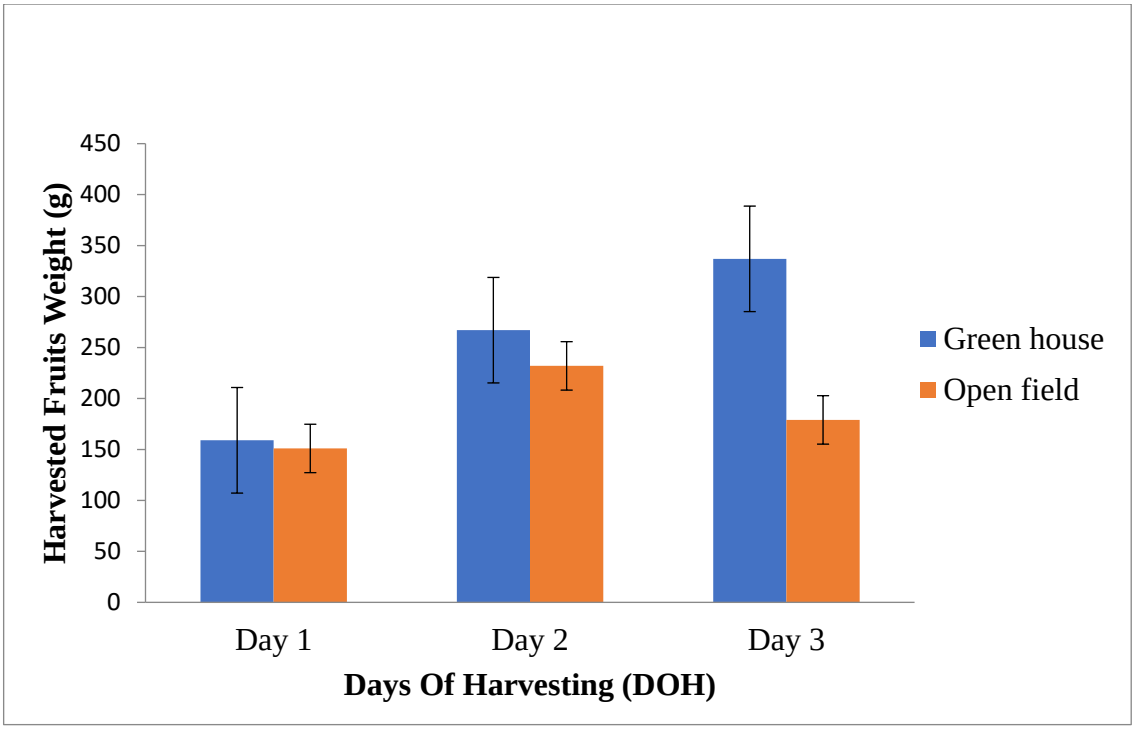

Figure 4.6: Effects of greenhouse technology on harvested fruits weight (g) 6

4.7 Effects of greenhouse technology on mature vertical fruit length (cm)

Figure 4.7 shows the effect of greenhouse technology on matured vertical fruit length. Greenhouse technology had significant ($P<0.05$) effect on the matured vertical fruit length. Figure 4.7, shows that at 1, 2 and 3 days of harvesting tomatoes plants grown under the greenhouse

4.8 Effects of greenhouse technology on mature vertical fruit diameter

Figure 4.8 shows the effect of greenhouse technology on matured vertical fruit diameter. Results from Figure 4.8 shows that, greenhouse and open field technology had significant ($P<0.05$) effect on matured vertical fruit diameter. The results revealed that, at 1, 2 and 3 days of harvesting, tomato plants grown under the green house technology recorded the highest ($P<0.05$) diameter in comparison with tomatoes plants grown in the open field.

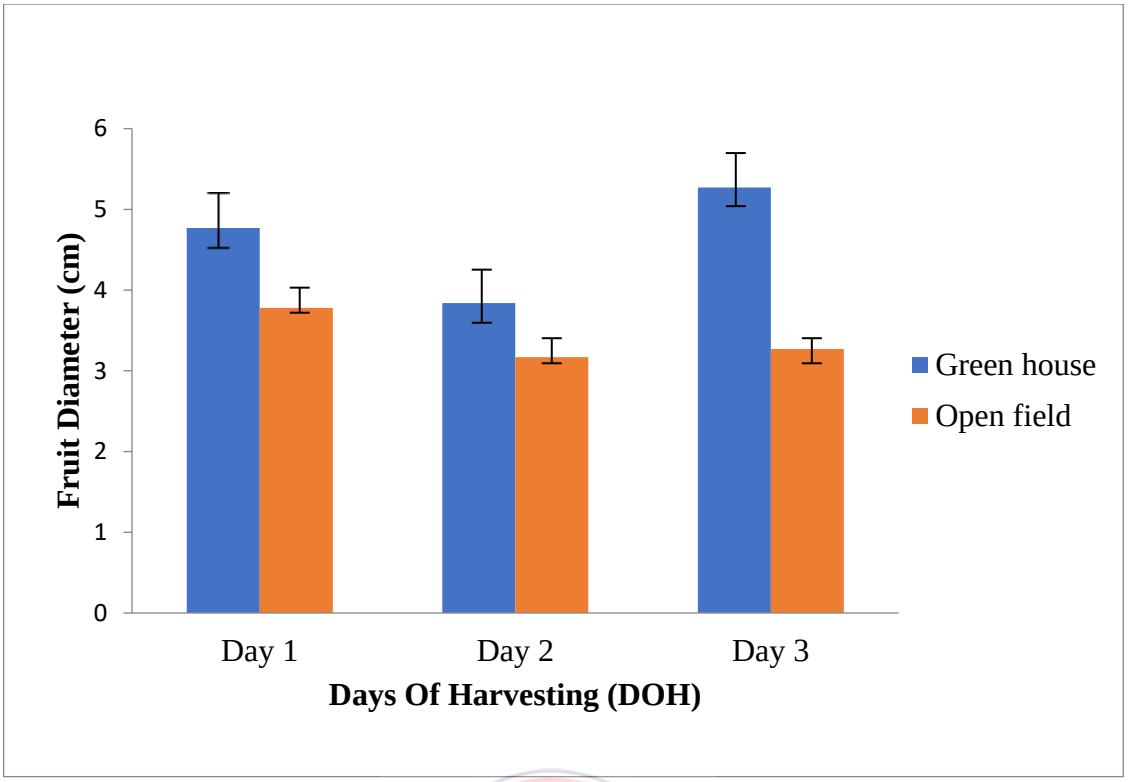

Figure 4.7: Effects of greenhouse technology on mature vertical fruit diameter 7

4.9 Cost of production, income and profit in tomato production

Tomato production under greenhouse technology had significant ($P<0.05$) effects on the production cost, income, profit generated from the sales of harvested fruits and value - cost ratio (Figure 4.9 and 4.10). A higher cost of production was observed for tomato plants cultivated under the greenhouse technology while tomato plants cultivated in the open field recorded the lower cost of production. On the other hand, income and profit margin generated from the sales of tomato fruits harvested from the greenhouse technology was higher ($P<0.05$), in other words, more profitable as compared with tomato plants cultivated in the open field.

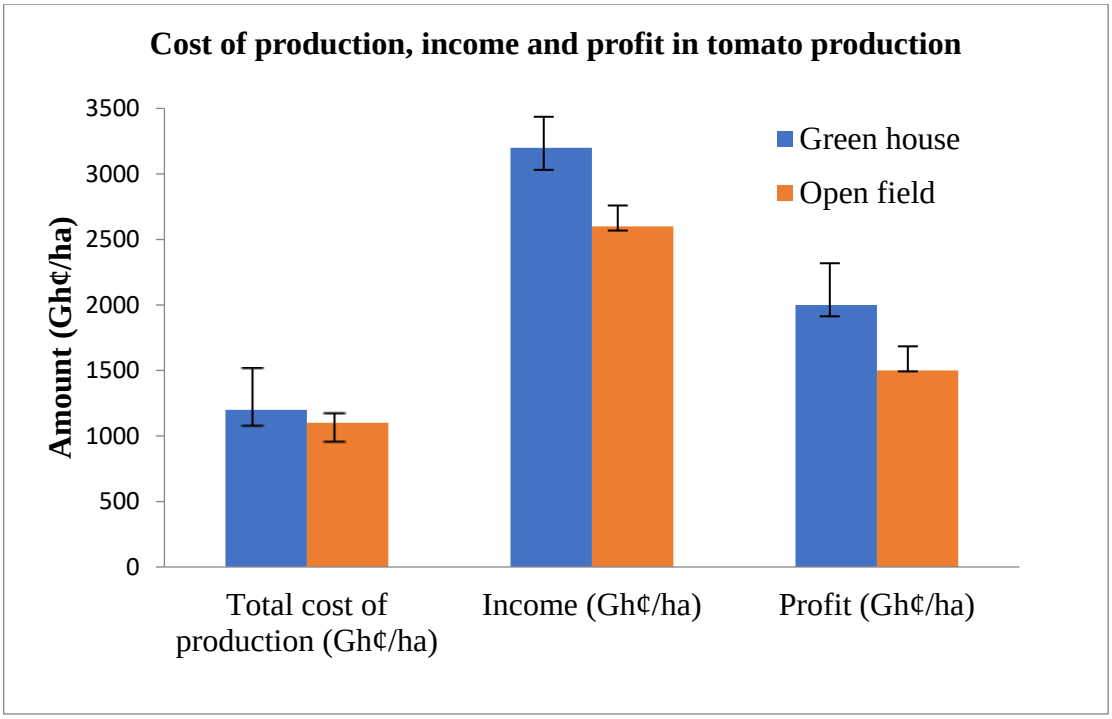

Figure 4.8: Cost of production, income and profit in tomato production under open field and greenhouse technologies 8

Results from the study as seen in Figure 4.10 revealed that tomato plants cultivated under the greenhouse technology and in the open field were above the economic threshold (2.0). However, tomato plants cultivated under the greenhouse technology was economically more viable since the VCR value was higher (VCR = 2.67) as compared to tomato plants cultivated in the open field (VCR = 2.36). The cumulative ranking for the treatments based on the VCR followed the order: greenhouse technology > open field.

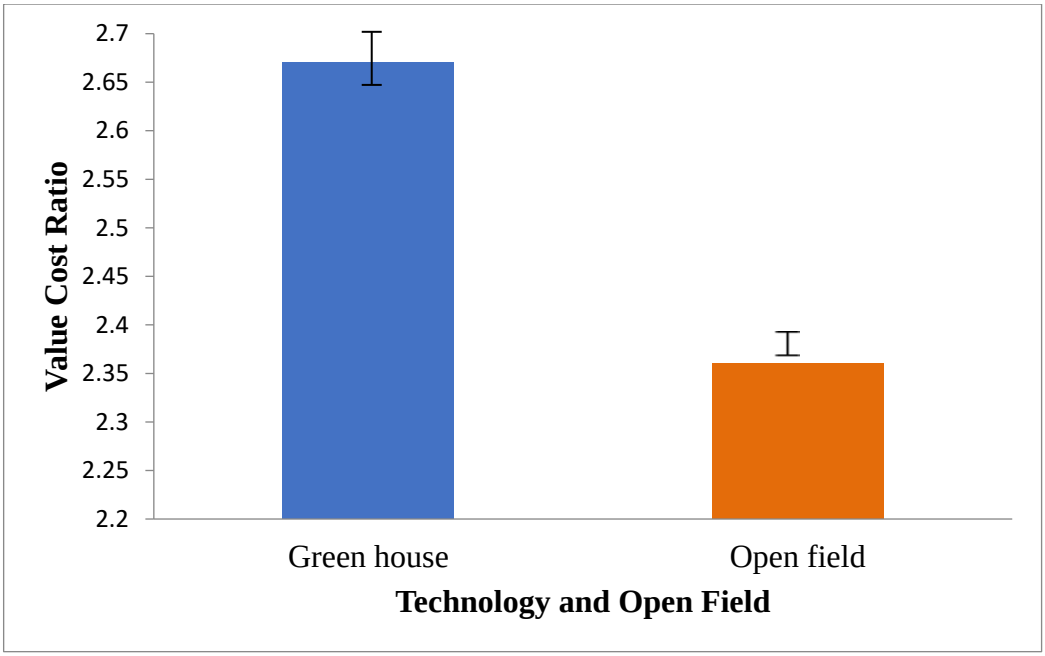

Figure 4.9: Value-cost ratio (VCR) in tomato production under greenhouse and open field technologies 9

CHAPTER FIVE

5.0 DISCUSSION

The variations observed in plant height could be attributed to the difference in temperature, water, light and soil nutrients. In this study, the average temperature within the day was higher in the open field which promoted higher production of plant growth hormones making the plants to grow faster as compared to tomato plants grown under greenhouse technology. Similar findings were reported by Pires (2011) who investigated into the impact of greenhouse models on plant growth and yield of tomato and observed that plants grown in the open field were taller than tomato plants grown in the greenhouse. Results did agree with those of Allen (2015) under open field environments. However, results of the study disagree with the findings of Yeshiwas *et al.* (2016) who reported that in greenhouse and open conditions, the taller height was observed among tomato plants grown in the greenhouse as compared to tomato plants grown in the open field conditions. On the other side of the results of the study, Anyega *et al.* (2021) also reported a significant taller plant in the greenhouse as compared with tomato plants grown in the open field. Yeshiwas *et al.* (2016) also reported better plant height in greenhouses as compared to open field conditions. The differences in plant height observed in this study and other studies could be attributed to the different geographical locations of the various studies and the differences in the prevailing environmental conditions. It obvious that when the plant grows tall, it will produce more flowers which will be directly proportional to the number of fruits they develop into hence higher economic gains.

The increase in the number of branches of tomato plants cultivated in the open field as compared to the green house technology could be explained that number of branches per tomatoes plant increased with the influence of daily temperature in the field as reported by

Angmo *et al*. (2021). This could be further explained that in the open field temperature and sunlight values were higher as compared with the greenhouse during the period of study. Angmo *et al*. (2021) reported that temperature and sunlight were higher in the open field as compared with the green house, and this influenced photosynthesis and transpiration resulting in the plant producing more branches. Results are in line with those of Paucek *et al*. (2020) under open field conditions. Similar facts were reported by Angmo *et al*. (2021) who observed higher number of tomatoes branches in the open field as compared with tomatoes grown in the green house technology. Results of the study contradicts with the findings of Meena *et al.* (2015) who reported higher number of branches among tomatoes plants grown in the greenhouse as compared with the open field. Kenwar (2011) also reported higher number of branches among tomato plants cultivated in the greenhouses as compared to open field conditions. The variations in the number of branches observed in this study and other researchers could be attributed to the prevailing environmental conditions as well as the nutrients in the soil. Since, the branches bear the fruits it is expected that the open field technology with the higher number of branches would bear the larger number of fruits.

The study also revealed that the higher stem girth observed among tomato plants grown in the open field could be associated to the higher temperature and sunlight (Bhattarai *et al.,* 2021). This could be explained that as temperature in the open field increases, photosynthesis, transpiration and respiration increases resulting in rapid stem development as reported by Teskey *et al.* (2015). Results are in conformity with those of Paucek *et al*. (2020) under open field conditions. Similar findings were reported by Palmitessa *et al*. (2020) who observed higher stem girth of tomatoes in the open field as compared with tomatoes grown in the green house technology. This made the plant difficult to log and

therefore, produce clean and attractive fruits to satisfy consumer preference hence more capital returns.

The current study reveals that higher number of flowers produced in the greenhouse could be explained that, tomato as a warm season crop requires temperature of about 24^{o}C to produce more flowers and this was observed in the greenhouse. According to Arnao & Hernández-Ruiz (2020) during the flowering stage of tomatoes, high temperatures delay the process of flower initiation. Weather records from the study show higher temperatures in the open field while in the greenhouse temperature was low across the period of study. Mathieu *et al*. (2020) reported that high temperature in the open field induced flowering abortion, which is mainly caused by the inhibition of capitulum development between inflorescence meristem formation and the growth of florets as observed in this study.

Similar findings were reported by Ezzaeri *et al.* (2018) who investigated into the impact of greenhouse models on plant growth and yield of tomatoes and found that plants grown in the greenhouse produced the highest number of flowers as compared with tomato plants grown in the open field. Results are in agreement with Yeshiwas *et al.* (2016) who reported higher number of flowers produced among tomato plants grown in the greenhouse as compared with the open field. Ro (2021) also reported higher number of flowers among tomato plants grown in the greenhouse as compared to open field conditions. The present study shows contradicts with the findings of Yeshiwas *et al.* (2016) who reported higher number of flowers among tomato plants grown in the open field as compared with tomato plants grown under the greenhouse technology.

Literally, the more the number of flowers the larger the fruits produced hence the better the harvest.

The number of fruits harvested could be explained that, the number of flowers produced were able to develop into fruits due to the favorable environmental conditions in the greenhouse. The outcome of the study confirms the findings of Rana *et al.* (2014) who reported higher number of fruits among tomato plants grown under greenhouse environments as compared to the open field. Jiang *et al*. (2017) also recorded significant differences for number of fruits and yield per ha. Ullah *et al*. (2021) reported that number of harvested fruits per plant were higher among tomato plants grown under greenhouse conditions and lower among tomato plants grown in the open field. When the harvest is the good the better the profit the farmer makes.

Fruit weight is a significant trait when recommending a suitable cultivar. Fruit weight is a very complex trait which is influenced by several weight components. In the current study, differences in fruit weight among tomato plants grown under the green house technology could be attributed to the temperature and favourable environmental conditions inside the greenhouse as compared to the open field. This could be explained that, tomatoes required suboptimal air temperature during the vegetative growth stage and this influence the plants to produce larger cells to store more starch leading to higher production of fruits with higher weight as reported by He *et al*. (2019). The outcome of the study agrees with the findings of Tringovska *et al*. (2015) who reported that yield per plant, yield per ha and harvested fruits weight per plant were higher among tomato plants grown under greenhouse conditions. Çolpan *et al*. (2013) also recorded significant differences for yield per ha. Çolpan *et al*. (2013) reported that harvested fruits weight per plant were higher among tomato plants grown under greenhouse conditions and lower among tomato plants grown in the open field.

Ro *et al.* (2021) reported that, the performance of tomato was generally superior in greenhouse cultivation compared to open conditions similar to the findings of the study. Akrami (2020) observed similar trends for yields per plant in greenhouses with respect to open field conditions. However, results of the study refute with the findings of Paucek *et al*. (2020) who reported harvested fruit weight was higher among tomatoes plants grown in the open field as compared with tomatoes plants grown under the greenhouse technology. Angmo *et al.* (2021) also reported poor yield in tomato under greenhouse as compared to open field crop because of higher temperature during growth, flowering and fruiting period in the green house.

Results of the study confirms the findings of Waiba *et al.* (2021) who reported that vertical fruit length was higher among tomatoes plant grown under the polyhouse technology as compared to the open field. Babu *et al*. (2020) also recorded higher vertical fruit length of 10.67 cm among tomato plants grown under the polyhouse technology as compared to vertical fruit length of 8.33 cm among tomato plants grown in the open field. All these values were higher than those found in the present study with the probable reason being fluctuating environment at fruit development as the present experiment was conducted under greenhouse and naturally ventilated open field.

Findings of the study agrees with the findings of Babu *et al*. (2020) who reported that vertical fruit diameter was higher (6.55 cm) among tomatoes plants grown under the greenhouse technology as compared to the open field (5.49 cm). Randhe *et al*. (2015) also reported higher vertical fruit diameter of 6.17 cm among tomato plants grown under the greenhouse technology as compared to vertical fruit length of 5.38 cm among tomato

plants grown in the open field. All these values were higher than those found in the present study with the possible reason being the season of cultivation, different environmental conditions and the geographical location of the studies.

The highest cost incurred for the greenhouse technology could be attributed to the high cost of materials purchased for the construction of the greenhouse. Hence, less amount of money was spent on the open field. This could be explained that tomato plants cultivated under the greenhouse technology had favourable environmental conditions as compared to tomato plants cultivated in the open field which was attacked by pest and diseases. The significant variations observed in the income and the profit margin among the greenhouse technology and the open field could be attributed to highest marketable fruits harvested in the greenhouse technology. Results of the study confirms the findings of Castillo *et al*. (2021) who reported that higher profit margin among tomato plants grown under greenhouse conditions as compared to the open field. Castillo *et al*. (2021) also recorded significant differences for income and profit margins.

Mutisya *et al*. (2016) reported that harvested fruits weight per plant were higher among tomato plants grown under greenhouse conditions which resulted in higher economic returns and lowest among tomato plants grown in the open field. The higher VCR value observed under the greenhouse technology was above the economic threshold (2.0) (Bashagaluke *et al*., 2020) and this is attributed to the higher marketable fruits harvested from the greenhouse technology. Again, the higher VCR above the threshold (2.0) observed in this study indicates the likelihood of greenhouse technology adoption by farmers.

CHAPTER SIX

6.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary

The objective of the study was to investigate into the effect of greenhouse technology on the growth and yield of tomato in the transitional zone of Ghana. The experiment was conducted at the Multipurpose Crop Nursery, of the former University of Education, Winneba currently AAMUSTED-College of Agriculture Education Mampong campus from 19th August, 2019 to 30th November, 2019. The experimental design used for the study was RCBD. The treatments were made up of greenhouse technology and open field. Parameters measured included: plant height, number of branches, stem girth, number of flowers, harvested fruits weight, matured vertical fruit length and diameter and economic analysis of the technologies. The data gathered were analyzed using the Students T-test using GenStat version 11.1 (2008). Results from the study indicates that the taller ($P<0.05$) plants at 1, 3, 5, 7, and 9 weeks after planting, were observed from tomato plants grown in the open field while tomato plants grown under the greenhouse technology recorded the shorter ($P<0.05$) plants.

Number of branches produced at 1, 3, 5, 7 and 9 weeks after planting were higher ($P<0.05$) among tomatoes plants grown in the open field and lower ($P<0.05$) among tomato plants grown under the green house technology. Tomatoes grown in the open field recorded higher stem girth in comparison with tomato plants grown under the green house technology at 1, 3, 5 and 7 weeks after planting. However, at week 9, after planting, tomato plants grown under the green house technology recorded higher stem girth in comparison with tomato plants grown in the open field. Tomato plants grown under greenhouse technology recorded higher number of flowers in comparison with the open field at 1, 3, 7

and 9 weeks after planting. However, at week 5 after planting, tomato plants grown in the open field recorded higher number of flowers in comparison with the green house technology. The higher number of flowers produced in the green house. The T-test results revealed that, at 1, 2 and 3 days of harvesting, tomatoes plants grown under the green house technology recorded higher ($P<0.05$) harvested fruit weight, vertical fruit length and vertical fruit diameter in comparison with tomato plants grown in the open field.

6.2 Conclusions

On the basis of the study conducted to improve tomatoes productivity using greenhouse technology the following conclusions were drawn:

- The study concludes that greenhouse technology increased the fruit weight and fruit size of tomatoes as compared to the open field.
- From economic point of view, greenhouse technology is preferably ideal for higher tomato productivity and profit.

6.3 Recommendations

Based on the results, the following recommendations are made:

- Farmers should adopt greenhouse technology, since it gave higher productivity and economic returns.
- Further studies should be conducted to validate the findings of the study.
- Further studies should be carried out to investigate the effect of greenhouse technology and different soil amendments on the growth and yield of tomatoes in the transitional zone of Ghana.
- Future researchers should conduct their studies on the post-harvested shelf-life of tomatoes obtained from the greenhouse compared with those in the open field.

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APPENDICES

Appendix A. Growth.

Growth is a permanent increase in size and number of branches of a plant or crop. In an Agronomist point of view, growth is an increase in dry matter accumulation.

Appendix B. Vegetative Growth.

This is the period of growth from germination to flowering. This is known as vegetative phase of plant development. During the vegetative growth phase, plants go through photosynthesis process and accumulation of resources that will be needed for flowering and reproduction. Has fleshy fruit and is variable in length, shape and diameter. The fruits are formed from …….ovaries with 2-9 locules. At the mature stage the coloration of the fruit changes from green to red, orange or yellow depending on the variety of tomatoes.

Appendix C. Reproductive Growth.

This is the phase of the plant life cycle where flower, fruits and seeds are formed. Tomato

Appendix D. Yield.

Yield of crop is a measure of the amount of agricultural production harvested- yield of a crop unit of land area. Crop yield is mostly used for cereals, grains, legumes and typically measured in tonnes per hectare or kilograms per hectare in Ghana. Harvested farm produce is mostly measured to determine the estimated crop yield.

Appendix E. Sterilization

Sterilization is a process that eliminates, removes kills or deactivates all forms of microbes such as fungi, bacteria, viruses, spores, unicellular organism such as plasmodium and other related biological agents in culture media. Soil steam sterilization if a farming technique

that sterilizes soil in open field or greenhouse. Parasites of plant culture such as weeds, viruses, fungi are killed or deactivated through induced hot steam which causes important cellular proteins to fold.

Appendix F. Fumigations.

Fumigations is a method of pest control that completely diffuses the area with gaseous pesticides or fumigants to suffocate the pests in soils, grain and farm produce. This method also affects the structure itself, pests that inhabit the physical structure, such as woodborers and termites.

Appendix G. Fertigation.

This is where fertilizer is mixed with irrigation water and then applied to plants.

Appendix H. Trellising.

Tomato plants must be supported, regardless of the growing system and this is called trellising or staking-providing support to the tomato plant.

Appendix I. Open Field

This is the normal practice where farmers cultivate crops on their farmlands.

Appendix J. Greenhouse

This is where crops are cultivated in an enclosed structure with the environment being controlled to reduced pests and diseases infestation and external stress.