UNIVERSITY OF EDUCATION, WINNEBA

EFFECT OF DIFFERENT PLANT SPACING AND STAKING ON GROWTH AND YIELD OF TOMATO (*Solanum lycopersicum L.)*

PRINCE YAW ASANTE

M.Ed AGRICULTURE (CROP SCIENCE)

2022

UNIVERSITY OF EDUCATION, WINNEBA

COLLEGE OF AGRICULTURE EDUCATION

MAMPONG-ASHANTI

EFFECT OF DIFFERENT PLANT SPACING AND STAKING ON GROWTH AND YIELD OF TOMATO (*SOLANUM LYCOPERSICUM L.)*

PRINCE YAW ASANTE

(190014425)

A dissertation submitted in the Department of Crop and Soil Sciences Education, Faculty of Agriculture Education to the school of Graduate Studies impartial fulfillment of the requirements for the award of Master of Agriculture Education in the University of Education, Winneba

MARCH, 2022

DECLARATION

STUDENT'S DECLARATION

I, Prince Yaw Asante, declare that this dissertation with the exception of quotations and references contained in published works which have all been identified and acknowledged is entirely my own original work and it has not been submitted either in part or whole for another degree elsewhere.

--------------------------------- --------------------------------

Prince Yaw Asante Date

(Student)

SUPERVISOR'S DECLARATION

I hereby declare that, the presentation of this thesis was supervised in accordance with the guidelines and supervision of thesis by University of Education, Winneba.

-------------------------------- -------------------------------

Dr Stephen Larbi-Koranteng Date

(Supervisor)

ACKNOWLEDGEMENTS

I would like to express my profound gratitude to my supervisor, Dr Stephen Larbi-Koranteng of Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED), Mampong Campus for his guidance, encouragement, advice and support for this work. I am most grateful.

My invaluable appreciation also goes to Dr. Michael Kwabena Osei, Bernard Osei and Michael Kudazeof CSIR-Crops Research Institute (CRI), Kwadaso, for their technical assistance, advice and guidance for this work. I cannot forget to mention Gibril Musah for his unflinching support towards the successful completion of this work. Finally, my heartfelt thanks go to my family, especially Amponsah Emelia and Joel Asante for their support and encouragement during my studies.

'Glory to the Almighty God,

DEDICATION

This work is dedicated to the late Linda Fremah for her love and support during my studies.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The study investigates the performance of staked and non-staked on Shasta tomato at different plant spacing. The experimental design used for the study was 2 x 3 factorial arranged in Randomized Complete Block Design (RCBD) with three replications. The treatment was up of three spacing; 50cm x 40 cm ,60 cm x 40 cm and 70 cm x 40 cm and two factors, staked and non-staked. There were six experimental plots with varying plot length of which each block contained six plots. The result shows that there was a significant ($P \leq 0.05$) difference between staking and No staking in yield per hectare. Staking produced significantly higher (1996kg/ha) yield per plant than No staking treatment with the least recorded (1801.0 kg/ha) in yield per plant.There was also significant ($P \leq 0.05$) difference betweenplant spacing of 50 cm x 40 cm, 60 cm x 40 cm and 70 cm x 40 cm in yield per hectare. Spacing 50 cm x 40 cm produced the highest yield per hectare while 70 cm x 40 cm produced the least mean of (1318.0kg/ha). The study further recommends that farmer should plant tomato No staking x 50 cm × 40 cm for potential yield 3352 kg/ha.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the study

Tomato (*Solanum lycopersicum* L.), belongs to the family Solanaceae. It is believed to have originated from the Peruvian and Mexican regions. The crop is adapted to a wide range of climates (Worlds Crop Database, 2012). It is one of the most accepted vegetables usually grown in the world. In Ghana, it is an essential ingredient in the diet of many people. However, tomato production in Ghana has not reached its potential, in terms of realizing yields comparable to other countries (FAOSTAT Database, 2015).

The world production of tomatoes has consistently increased since 2000, growing more than 54% from 2000 to 2014 (FAO, 2017). China is the largest producer of tomatoes, followed by the United States and India. Other major players in the tomato market are the European Union and Turkey. Together, these top five tomato producers supply around 70% of the global production. Mexico is the largest exporter of tomatoes in the world, followed by the Netherlands and Spain (CIA, 2017). In 2016, Mexico, the Netherlands, and Spain accounted for 25.1% ($2.1 billion), 19% ($1.6 billion), and 12.6% ($1.1 billion) of the world's total tomato exports, respectively (CIA, 2017). In the United States, approximately 35 billion pounds (16 million tons) of tomatoes were produced in 2015; about 8% of the total production was fresh tomatoes, which have much higher prices than processed tomatoes.

However, Ghana ranks 48th in the production of tomatoes worldwide, producing 366,772 Mt annually (FAOSTAT, 2016). Tomato production in Ghana has reached levels in the region of 400,000 metric tonnes MOFA (2018). Ghana, a major net exporter of food items some few years back, is now one of the major net importers of most daily consumables including tomatoes (Trade Statistics, 2014). Ashanti region, Ahafo region, Greater Accra, Bono region, Volta region and northern partsof Ghana are among the areas where tomato cultivations are mostly carried out, where dry season cultivation lies in the Savannah zones, particularly Upper East, Volta and Greater Accra since dry season water for irrigation is not a limiting factor MOFA (2019). However, tomato production has been an important agricultural venture in the northern part of Ghanaby providing employment from generation to generation during both dry and rainy seasons. A survey report by Trade Aid Integrated, an NGO, pointed out that tomato production gave employment to about 11,728 farm families from the Upper East region and with an average family size of 5 persons. It is estimated that 58,640 persons benefit from its production (Glover, 2007a). Tomatoes and tomato-based foods provide a convenient matrix by which nutrients and other health-related food components are supplied to the body. In areas where it is eaten, it forms a very important part of human food (Beecher, 1998).

Tomato, for example, forms a very important component of food consumed in Ghana and this is evident in the fact that many Ghanaian dishes have tomatoes as a component ingredient (Tambo and Gbemu, 2010). Tomato is a rich source of folate and with phytonutrients, the most abundant in tomatoes are the carotenoids, lycopene being the most prominent, followed by beta-carotene and gamma-carotene, photoene as well as several minor carotenoids (Beecher, 1998). In spite of the modest levels of beta-carotene and gamma-carotene in tomato products, due to their provitamin, a high consumption of the vegetable and its products results in a rich supply of vitamin A in the body. Lycopene, an antioxidant, purportedly fights the free radicals that can interfere with normal cell growth and activity. These free radicals according to Filippone (2006), can potentially lead to cancer, heart disease and premature aging.

These nutritional facts are good reasons to support the tomato industry of Ghana as far as the production, storage, processing, distribution and consumption are concerned. It has been reported that, people of Northern Italy who ate seven or more servings of raw tomato every week had 60% less chance of developing diabetes (Choudhury, 1975). Moreover, tomatoes are usually required to prepare soup or stew to accompany Banku, TZ, Fufu, Plain Rice, Jollof rice and other major staple food. However, like many other vegetable crops, tomato production remains a smallholder activity with very few commercial farms (FAO, 2005).

1.2Problem statement

In spites of all these importance attributes of tomato, the production of the crop is still mainly in the hands of peasant farmers in Ghana. The demand for tomatoes, especially during the dry season, which eats into the Christmas period becomes a challenge. In order to meet the demand, there is the need for heavy importation of fresh tomato from neighbouring countries particularly Burkina Faso to boost local supply (Melomey*et al.,* 2019). This small quantity of tomato production, has made Ghana a net importer of tomatoes from Burkina Faso over half of the year (Horna*et al.,* 2006).

Again, the tomato sector has been described as a "low-productivity high-cost" sector (Robinson and Kolavalli, 2010). The yield gap is quite huge while the annual attainable yield for tomatoes in Ghana is 15 metric tonnes per hectare (MoFA, 2011). The actual yield is now about 7.5 metric tonnes per hectare (MoFA, 2011). This gives a yield gap of 50% (MoFA, 2011). In 2003 and 2004 Ghana exported 4,368 and 607 metric tonnes of tomato respectively which confirmed it production in Ghana in those days (FAO, 1995).

This indicates that, there is a drastically declining of the production of tomato in Ghana.One of the problems of poor performance of tomato in Ghana is due to non-adoption of improved husbandry practices in tomatoproduction, especially staking, proper spacing etc.

However, most peasant farmers allow the vines to trail on the ground leading to the production of fruits with dirty skin. Moreover, planting the crop haphazardly by most peasant farmers without proper spacing, the crop then competes for nutrients, water and sunlight with the weed which effects is low production level incurred by these peasant farmers. The overcrowding of the vines and subsequent attack by pest and disease due to high humidity leads to rotting of fruits. However,it has been observed that with good cultivation practices the yield of tomato could reach 22,000 - 27,000kg/ha (22 – 27 tonnes per hectare) for a field in the Accra plains (Sinnaduiai, 1992).

Therefore, a good cultivation practices including staking and proper spacing of tomato production is required to address this problem that most peasant farmers are encountering.

According to Akoroda *et al.* (1990) and Trenbath (1976), the idea of staking facilitates harvesting of vegetable and pods and also exposes the leaves for effective light reception. Moreover, spacing affects growth, yield and quality of tomatoes as well as pest and disease prevalence. Spacing is among the management practices which greatly influence tomato fruit yield (Abdel-Mawgoud*et al.,*2007). However, few studies have been conducted to assess the influence of different plant spacing and staking on growth and yield of tomato. It is in light of this knowledge gap that this study is seeking to identify the best production practice in planting spacing and staking for growth and yield of tomato

1.3 Justification

The Statistical Service Department (SRID) of the Ministry of Food and Agriculture (MoFA, 2013) reported that, the country spends approximately GH₵ 1.4 million importing tomatoes. The commodity is imported to support the rise in demand for the good. Particularly during the off-peak season, home output is pitifully unable to meet demand. The product is in high demand at the household level and is a significant component of many Ghanaian meals. In Ghana, it is nearly a necessary item in people's daily diets across all Regions. Tomato alone accounts for 38% of total vegetable expenditure in Ghana(Agyekum, 2015). Consumption of tomatoes in the country is a daily affair in the lives of many Ghanaians as it is present in virtually all meals. About 70,000-80,000 tonnes of tomatoes are currently imported from neighbouring Burkina Faso, into the country to augment increasing demand for fresh tomatoes (Agyekum, 2015).In order to increase the yield gap of tomato production in Ghana, the search for adoption of improved husbandry practices in tomatoproduction has been intensified in recent year. Adaptation of staking and spacing to improve the yield of tomatofor our traditional farmers through conventional method could be cheap and easier.Trinklein(2010) supported the idea that proper spacing is essential for healthy plants and good fruit production. Staking and spacing are major contributing factors that may improve the yield of tomato cultivation for our peasant farmers. Staking increases fruit yield, reduces the proportion of unmarketable fruit, enhances the production of high-quality fruits, prevent disease and fruit rot, allows better aeration and better exposure of the foliage to sunlight and photosynthetic activities (Alam*et al.,* 2016). The information obtained from this study will assist farmers to adopt good husbandry practice that will minimize loss of tomato yield. This will therefore help farmers to improve income, food security as well as achieving Ghana’s self-sufficiency in tomato production. The study would also serve as a reference for all stakeholders for the production of tomato in Ghana.

1.4 Objective

1.4.1 Main objective

The main objective of this study is to investigate the performance of staked and unstaked tomato at different plant spacing.

1.4.2 Specific objectives

Specific objectives were to:

- Assess the effectiveness of staking on the performance of tomato
- Determine the effects of different plant spacing on the growth and yield of tomato.
- Identify the interactive performance of staking and spacing on yield of tomato.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Originand Distribution

The native land of wild tomatoes (*Solanum lycopersicum*) is Western South Americaand is part of the solanaceae family (Knapp & Peralta, 201 6). Many years after itsdiscovery it was grown as an ornamental until the 1 6th Century when it was firstaccepted as a vegetable crop in the southern part of Europe (Ames & Spooner, 2008). Tomato is a widespread crop which has the tendency to grow in diverse habitats. Therefore, it is distributed throughout Columbia, Mexico, Bolivia, other South American countries, Asia and many parts of Africa. Tomato is one of the major vegetable crops on the world market and forms an essential part of human diet (Ames & Spooner, 2008).

Mostly, tomato is cultivated on a large scale under greenhouse and open field conditions (Mehnaz*et al.,* 2010). Some people believed that the origin of domestication of tomato originated from Peru, whilst others believe that it originated from Mexico (Ames & Spooner, 2008). Bauchet& Causse (2012) noted that it was in Peru that tomato became diversified, but domestication of tomato was in Mexico. New tomato varieties are being identified and conserved by plant breeders' worldwide (Ames &Spooner, 2008). Tomato plant was first introduced into West Africa, Eastern Africa, and Central Africa during the 1 6th and 1 7th centuries (Leke*et al.,* 2015). It is extensively cultivated in Burkina Faso, Nigeria and Ghana (Bellwood-Howard *et al.,* 2015).

2.2Botany

Tomato plants have several botanical descriptions and are broadly classified as reproductive and vegetative.

2.2.1 Vegetative description

Tomato is a dicotyledonous crop with a tap root system. It grows to a height of 50cm, its stem girth can grow to about 2 to 4cm long (Agbaglo, 2017) and has dense lateral and adventitious root. Tomato plants have fragile, hairy and woody stem. Attached to this stem is its compound leaves made of spirally arranged leaflets which are oblong or ovate (Dharani, 2011). Based on its growing habits tomato plant can be classified as determinate, semi- determinate and indeterminate. The indeterminate plants grow very high and mostly need staking. Whereas, the determinate type needs no support and stop growing at 1 .5m when the flowers form at the terminal growing point (Agbaglo, 2017).

2.2.2. Reproductive description

Tomato plant is characterized by its yellow flowers. Its flowers are less than an inch in diameter and can occur in either a simple or complex inflorescence of about 6 to 1 2 bisexual flower (Van der Linden & Farrar, 2011). Temperature is one environmental factor that influences the formation of the inflorescence (Petrie &Clingeleffer, 2005). Agbaglo (2017) indicated that tomato flowers are self-pollinated (autogamous). In some cases, cross pollination may occur with the aid of pollinators such as wind, insect or animals (Agbaglo, 2017). The style has a sterile tip which is elongated and around the style are six (6) stamen and anthers that are also yellow.

The stamen and carpals are involved in the reproduction process of the tomato plant. The pollen produced in the stamen fertilizes the carpals. The fertilized ovule then develops into an embryo which consequently matures to form a seed. The seed is wrapped with flesh within a mature fruit. 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 colouration of the fruit changes from green to red, orange or yellow depending on the variety of tomatoes. Determinate tomato fruits ripen faster than the indeterminate types. Agbaglo (2017) states that coupled with the high leaf to fruit ratio and the slow rate of ripening, indeterminate tomato fruits taste better than that of the determinate.

2.2.3 Ecology

Tomato is a warm season crop; it is very tender crop. Though it can grow in a wide geographical area, it cannot withstand frost and shows the appearance of minimal chilling at the fruit ripening stage (FAOSTAT, 2014). The optimum temperature required for high quality growth of tomatoes is cool dry temperature at 20ºC to 27ºC. For tomatoes to mature early it has to have periods of warm nights with high soil temperatures (FAOSTAT, 2014).

2.3Global tomato production

Tomatoes are one of the world's most consumed vegetable crops. According to statistics from the Food and Agriculture Organization (FAO), around 340 billion pounds (170 million tons) of fresh and processed tomatoes were produced globally in 2014 (FAO, 2017). The harvested area covered 12.4 million acres (5 million hectares) of farmland. The world production of tomatoes has consistently increased since 2000, growing more than 54% from 2000 to 2014 (FAO, 2017). China is the largest producer of tomatoes, followed by the United States and India. Other major players in the tomato market are the European Union and Turkey. Together, these top five tomato producers supply around 70% of the global production.

Mexico is the largest exporter of tomatoes in the world, followed by the Netherlands and Spain (CIA, 2017). In 2016, Mexico, the Netherlands, and Spain accounted for 25.1% ($2.1 billion), 19% ($1.6 billion), and 12.6% ($1.1 billion) of the world's total tomato exports, respectively (CIA, 2017). In the United States, approximately 35 billion pounds (16 million tons) of tomatoes were produced in 2015; about 8% of the total production was fresh tomatoes, which have much higher prices than processed tomatoes. In 2015, the total values of fresh and processed tomatoes produced in the United States were $1.22 billion and $1.39 billion, respectively (USDA-AMS, 2017).

2.4Production in Africa

In Africa, an estimated 18,648,548 metric tonneswere produced in 2013 representing about 12% of the world's production. North Africa recorded the highest production, with an estimated 12,753,255 metric tonnes, out of which Egypt produced anestimated 10, 000,000 metric tonnes. Till today, Egypt remains the leading producer in the continent. West Africa placed second, producing 2,744,905 tons, East Africa, Central and Southern African followed with 1,544,766, 1,026,113, 579,509 metric tonnes respectively (FAOSTAT, 2015). According to UNCTAD (2015), Nigeria is the leading producer of tomatoes in West Africa, producing between 1,000,000 - 2,000,000 tons of tomatoes in 2009 and placing first among the African, Caribbean and Pacific (ACP) countries whilst Ghana placed eighth.

2.5Tomato production in Ghana

Agricultural production in Ghana is generally characterized by small scale farming with high incidence of market failures and other negative factors which lead to low yields. The Ministry of Food and Agriculture reported that, tomato is cultivated on an estimated 50,000 hectares of land with its production standing at 48% of its achievable yield (MoFA, 2013). In Ghana, emphasis on non-traditional exports became prominent after the Structural Adjustment Programme (SAP) had greatly affected the sector (Asuming-Brempong and Bruce, 2004). Ghana, produced approximately 200, 000 to 250, 000 metric tonnes of tomatoes between 2008 and

2009 (UNCTAD 2015). By the close of 2013 season, Ghana had hit a production level of 340,218 metric tons (FAOSTAT, 2015).

Although information on general yields in the sector is sketchy, it is obvious the sector records low yields (Al-hassan and Diao, 2007). A study by IFPRI (2008) revealed that, although natural hindering factors generally affect agriculture in Ghana, the vegetable sector suffers the most. Surprisingly, the recent work of Donkoh*et al.* (2012) revealed that, tomato producers in the Upper East Region of Ghana are technically efficient. Although technical efficiency does not generally mean high yield, the former leads to the latter.

The history of commercial tomato production in Ghana dates back to the 1960s (Donkoh*et al.,* 2012), for instance, the Vea Irrigation Project was built in 1965 to enable commercial production of many agricultural commodities including tomatoes. By 1980, Ghana had constructed a number of tomato processing factories for its expanding industry. Donkoh*et al.,* (2012) again observed that, the move had strategically reduced power and exploitation by the market Queens, since many of the farmers were engaged in contract farming with these factories. The establishment of the Pwalugu Tomato Factory was to strategically give the Tono and Vea irrigation scheme a ready market for its output (ICOUR, 1995). In the same vein, the establishment of the Tomacan tomato factory at Wenchi was to help boost production at Brong Ahafo and its catchment areas likewise the Techiman Tomato processing factory.

Ochieng and Sharma (2005) as cited by Adimabuno (2010), argued that the sector was so viable that people in the Upper East Region preferred tomato production to other crops such as maize, rice, groundnuts, yam among others. Many communities that were engaged in tomato farming generally had increased access to commodities that were engaged in tomato farming generally had increased access to commodities such as motorbikes, bicycles etc. (Laube, 2005). Adimabuno (2010) observed that the cultivation of tomatoes was hailed by all in the community and remained an attractive venture.

In view of the numerous benefits that accompanied tomato production, described as the red gold of Upper East Region, many other communities, even without access to water sources, had to engage in shallow wells dug out just to benefit from the industry (Blench, 1999). The tomato industry remained an enviable sector until the nation under the pressure of economic meltdown signed unto the Structural Adjustment /Economic Recovery Programme (SAP/ERP). The introduction of SAP/ERP, which led to the eventual privatization of many state enterprises including the tomato factories marked the beginning of the failure of the tomato industry (Asuming-Brempong and Bruce, 2004; Robinson and Kolavalli 2010, Donkoh and Amikuzuno 2012).The scraping of tariffs led to flooding of the Ghanaian markets with cheap tomato paste, it is estimated that between 1993 and 2003, tomato paste imports had increased by 628% from 3,713 tonnes to 27,015 tonnes (Donkoh*et al.,* 2012).

Konings (1981), remarked that, many of these factories began to face technical problems, input shortages, which badly affected productions. The removal of import tariffs and scraping of subsidies further worsen the woes of the industry. Farmers had to produce at a high cost, while the factories which were no longer protected faced stiffer competitions. This led to a massive reduction in the aggregate demand for the fresh product as well as production. The end result was the collapse of many of these factories, leaving peasant farmers to the mercy of any trader willing to buy this highly perishable product. The farmers had produced but the factories which one time provided the "big demand" could not buy any more, leading to huge losses on the part of farmers.

2.6Varieties

Over 7,500 varieties of tomatoes are discovered and cultivated for various purposes (Korir*et al.,* 201 4). They are therefore classified by the shape, size and use. These classifications are the cherry, beefsteak, plum, globe and grape (Adejuwon, 2017). Globe or slice tomatoes are also known as round tomatoes and are mostly used in the preparation of dishes and for processing. 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. 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. The grape type which is slightly smaller than the plum type was recently discovered and is also used in salads. Pear shaped tomatoes are sometimes grown.

Tomato varieties can also be classified as either determinate or indeterminate. With the indeterminate type, it forms vines however, this vine does not fall off if proper conditions necessary for growth are provided to the plant. It is capable of fruit set throughout a growing season. Therefore, it is preferred by people who grow at home and commercial growers that serve the fresh market. The determinate types are bushy and harvesting is done at once. It is preferred by commercial farmers who wish to harvest once for tomato processing into pastes and purees (Kalloo, 2012). Topping off occurs at specific plant height during the growth of the plant. They are mostly used when growing in pots or bags. Majority heirloom types are indeterminate, although few are determinate. Semi determinate tomato variety is also known as vigorous determinate. It forms one more fruit set after the first fruit set and yet tops off like the determinate varieties.

2.7Major tomato varieties grown in Ghana

According to a Ministry of Food and Agriculture resource (2008), the recommended varieties of tomato in Ghana are the Roma VF, Pectomech, Pectomech VF, Tropimech, Rio Grande, Cac J, Wosowoso, Laurano 70. The main source of seeds by farmers is reputable seed dealers. Robinson and Kolavalli (2010) describe the Pectomech variety as suitable for processing and preferred by consumers and achieving a premium price over the local varieties. Clottey *et al.*(2009) in their research on the tomato industry in Northern Ghana reported the major tomato varieties in Vea, a notable tomato growing area as Pectomech, Tropimech, Roma and a variety the farmers could not name. Adubofour*et al.* (2010) also cited two varieties of tomato grown inGhana as the Bolga and Ashanti.

Other authors such as Robinson and Kolavalli (2010), described other varieties as Power Rano, grown widely under rain-fed conditions and being the variety that is grown widely in Brong Ahafo Region and “No name”, another variety believed to be Pectomech and widely grown in the Upper East Region under irrigated condition. They also cited other varieties as “Burkina”, grown under rain-fed conditions mostly in the Grater Accra Region and believed to be a Pectomech from Burkina Faso. Other varieties are Nimagent F1, supplied by Trusty Foods, grown under both irrigated and rain- fed conditions in the Greater Accra Region and Ada Lorry Tyre and Meenagiant all mostly grown in the Greater Accra Region under rain fed conditions.

Lastly, Robinson and Kolavalli (2010) mentioned yet another variety as Techiman, grown under rain-fed conditions in the Greater Accra Region and under irrigated condition in the Upper East Region. Identifying key local open pollinated varieties that farmers can wash and recycle, they mentioned varieties such as Rasta, Power, Power Rano, and Wosowoso, with Power Rano often being preferred due to its high tolerance and/or resistance to diseases.Ellis *et al.* (1998) describe the `Power' variety as the predominant variety for cultivation in Ghana.

2.8 Tomato as a food

Tomato was not eaten until the nineteenth century because Mattiolus had called it mala insane (unhealthy flower) and scientific textbooks kept insisting it was poisonous. In North America, tomato became common in the early part of the 1 9th century (Fry, 2008). As in most of Europe, tomato was considered poisonous until its acceptance around 1840 as a nutritious vegetable (Huang *et al.,* 2017). This is because the tomato was considered poisonous for having similar qualities of poisonous plants when it was first introduced to the Europeans. People were reported to have gotten sick from eating it but this, according to Macdiarmid*et al.* (2013) might have come from their plates they ate from and not from the tomato itself. Plates were made from pewter, a soft metal that often-hadled, a very poisonous metal which could be caused to seep out by the acid in tomatoes.

However, Barceloux (2008) and (2009) wrote that like many other plants in the nightshade family, tomato leaves and stems contain atropine and other alkaloids including the tomatine that can be quite toxic if ingested. Huang *et al.* (2017) believe that the Italians were probably the first group of Europeans to eat the tomato. This claim is from a written record by Mattiolus where he is said to have described human consumption of tomatoes with oil and salt, suggesting that tomato was already established in the Italian cuisine by the early 16th Century this contradicts Fry (2008) who reported Mattiolus to have described the tomato as poisonous.

2.9 General characteristics

The tomato plant is unusually sensitive to rapidly changing conditions in the surrounding environment, radiation intensity, air temperature and humidity, and that in the rooting medium, moisture and temperature levels, primarily affect fruit set and development (Flore, 2011). When Solar Radiation has low intensity or low hours of radiation, plant vegetative growth will be slow and fruit set are poor; with high light intensity also, poor fruit set also occurs. Light intensity has been shown to affect the net assimilation rate of crops (Archontoulis*et al.,* 2005). According to Khaddy (2015), the best growing environmental conditions are full morning sun, shade from high moon light intensity and partial shading in the late afternoon when light intensity radiation is high. Fresh market tomatoes are usually marketed by fruit type. These types include full -size globe (red or yellow), plum (Roma), and cherry. Consumers buy tomatoes primarily for their appearance but are attracted to repeat purchases by flavor and quality.

Tomatoes are very sensitive to mishandling and improper storage conditions. Because they can be injured by either low or high temperatures, proper postharvest handling and storage methods are essential for maintaining acceptable quality and promoting long shelf life.

2.10 Quality characteristics

Consumers and producers' preferences are very significant in the varieties farmers choose to cultivate as these qualities must be satisfied by the farmers to be able to have very competitive goods on the market. Tieman *et al.* (2017) suggests that since consumer preference is key in tomato production there is the need to evaluate the cultivars on the market to find superior varieties. Also, there was the need to develop new tomato varieties that will meet consumer preference. Shewfelt (2014) pointed out that to be able to evaluate tomato fruit quality its physical and chemical characteristics must be determined. Fruit flavour, firmness, uniform colouration, sweet taste (i.e., high sugars and low acids) is a major determinant of fruit quality that influences consumers.

For the processing companies'traits, they look for are pH of fruit, total soluble solids and taste of fruit (Beckles, 2012). The qualities outlined above also dictate a number of other quality traits including beta-carotene, lycopene, flavonoids, phenolic acids, ascorbic acids and sugars. Not only genetic factors affect the production of these components, the environment the crop grows in and the interaction effect between genetic factors and environmental interactions ((Beckles, 2012). Currently lots of research is focused on growth, yield, development and improvement of tomato plant (Lee *et al.,* 2010).

2.11 Nutritional benefits

Tomato is one of the very important vegetables and its fruit forms a vital part of the diet of a number of people in the world as its total contribution to human nutrition far outranks other vegetables (Englberger& Johnson, 2013). High content of minerals, vitamins 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 (Skrutvold, 2014).

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 tomato fruit have (Lima et al., 201

4) Obesity can be checked by consuming the tomato fruits (Abdul Hammed et al., 2009). Yu and Sacco (2005) reported that excretion of certain cancerous cells can be inhibited by flavonoids and lycopene, which is contained in large amount in tomatoes. While, Bhowmik et al. (201 2) indicates that the antioxidants in tomatoes protects the human cells from oxidants that destroy the cells and causes cancer of the stomach, lungs, endometrium, pancreas oesophagus, pharynx and colon. Tomato can also protect the skin from skin diseases and sun burns. Tomatoes are best preserved by washing thoroughly and keeping out of sunlight in a basket at room temperature. It can also be processed into purees and paste. It must not be placed in the refrigerator or fridge as it absorbs water and loses its flavour (Shidfar*et al.,* 2011).

2.12 Economic benefits

Tomato plant has great economic relevance all over the world. In Ghana it is the second most relevant vegetable after garden egg plants (Bonsu, 2017). Since tomatoes forms a part of most of the diets of people in the world, it has high value on both local and foreign markets. Its high value gives a lot of income to countries both on the domestic front and the foreign market (Jarosz, 2008). In Ghana, per capita consumption of tomatoes is a little over excess of 1 00,000 metric tonnes annually (Aduhene-Chinbuah,2018).

FAOSTAT reported in 2005 that in the year 2003, Ghana accrued US$47,000 as foreign exchange from production of 4,368MT of tomatoes. However, Ghana Export Promotion Council also in 2009 reported a decrease in export amount by approximately 18.5Mt. Tomato plants are well suited for different cropping systems and can be intercropped with many crops. Tomato also provides the rural and urban dwellers of many countries with employment opportunity. Trade Aid Integrated in a survey conducted in 2007 indicated that the Upper East Region of Ghana is one of the leading tomato producers in the country and provides employment for approximately 11,728 families. Aduhene-Chinbuah(2018) also reported roughly about 58,640 persons employed in the tomato production chain in Ghana.

2.13 Major tomato productionseasons in Ghana

Tomato production in Ghana is not uniform and varies from production area to production area. Major tomato growing communities in Ghana are Bolgatanga in the Upper EastRegion, Begoro, Oda and Nsawam in the Eastern Region and Agogo, Kumawu, Akomadan in the Ashante Region. The rest are Derma, Techimantia, Tuobodom, Tanoboase, Amoma and DormaaAhenkro in the Brong Ahafo Region and the capital, Accra in the Greater Accra Region. Tomato cultivation in the year begins at Bolgatanga in the dry season. Cultivation is under irrigation.

The Begoro production area follows from January 10 to February 10, harvesting by April. Next is the Kumawu area, from early February to early March. Tanoboase, Amoma, Tuobodom and Agogo have the same growing plan. They do their nursery from the mid-February to mid-March. There is only one-week interval between this growing season and that of Akomadan. Although a few farmers in the Derma/Techimantia/Dwomo production area begin in February, the majority begin their nursery establishment from mid-March to mid-April. The Oda production areas establish their nurseries in early May, transplanting in June.

The last group to get on is the Dormaa production area, where nurseries are established either in September or mainly in October. They mostly do water their crops and do harvest their produce around January where there is severe drought. They have only one growing season in a year. With the exception of Bolgatanga where they operate fully under the irrigation and the Dormaa and Accra production areas where they most often do water their crops, all the others operate a rain-fed production system (Mensah, 2010, National Best Tomato Farmer). The minor season begins with Nsawam between late May and early June. This is followed by Accra by early June and then by Begoro by mid-June and Tuobodom by late June. By early July towards the end of the month, the Techimantia, Derma and Dwomo growing areas do their nursery. Oda has no minor production season so do produce once in a year like Dormaa. Aside the major and minor rainy seasons productions as in detail described above, some areas such as Tuobodom, Derma, Dwomo and Techimantia in the Ahafo region of Ghana do have a third production seasonduring the dry season and fully irrigated. This system is locally referred to as 'Petraa'

2.14 Constraints of tomato production in Ghana

Tomato yields in Ghana (7.5 tons/ha) does not reach its potential (15 tons/ha) and yet other neighboring countries such as Burkina Faso produce about 1 2.5 tons/ha it results in Ghana importing from Burkina Faso to make up for the short fall in production (Amoah *et al.,* 2017). The low yield in tomato production is due to a number of constraints such as high post-harvest losses during the peak production season due to lack of processing facilities, poor seed sources- 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 seeds sources are usually not of high quality and 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, and pest and diseases, high cost of agricultural inputs (i.e. fertilizers, pesticides, seeds, water charges, tractor services, etc.), high rent charges, no land for expansion, no places to relocate nurseries, no storage facilities, difficulty in accessing credit, lack of capital to invest in the production, among others are some other constraints farmers face (Amoah *et al.,* 2017).

2.15 Some challenges associated with tomato production

Excessive rainfall can harm a tomato crop, particularly if it is not staked, due to the spread of leaf diseases in humid conditions (Gleason & Edmunds, 2005). A lot of physiological problems are associated with tomatoes (Etebu *et al.,* 2013) due mainly to specific adverse environmental conditions.

2.15.1 Blossom-end rot

Blossom-end rot is a calcium deficiency that occurs at the blossom end of the fruit (Etebu *et al.,* 2013). It is a condition where by black necrotic sunken tissue(s) are formed at the blossom end of the fruit. The necrotic tissue formed at the blossom end of the fruit does not change the entire nutritive values of the fruit, but only affects that portion which can make the fruit unattractive to consumers. Blossom-end rot develops very early in fruit formation when the fruit is smaller than a fingernail, which is a critical time for calcium deposition in newly forming tissue. Calcium is relatively immobile in plants. Once it becomes part of the plant tissue in one location, it cannot be easily moved to new developing tissue (Etebu *et al.,* 2013).

Furthermore, calcium moves in the water stream of the plant's vascular tissue. So, during hot, dry conditions with high transpiration, calcium uptake may be high but may not be moving laterally into forming fruit. This results in deficiency in these developing tissues even though there is sufficient calcium present in the soil. Blossom end rot is common in un-staked and unpruned plants.

The problem can be alleviated with even moisture regime during plant growth. Irregular watering as well as over-watering tend to aggravate the problem. Exogenous applications of calcium as foliar sprays have been suggested to alleviate the problem (Etebu *et al.,* 2013).

2.15.2 Flower abortion

Tomato is a warm season crop and needs relatively moderate temperatures to set fruit. Night time temperatures above 21 °C will cause flower abortion which in turn will reduce yields (Etebu*et al.,* 2013). In extreme temperatures such as high daytime temperatures (above 29 °C), high night-time temperatures (above 21 ° C), or low night time temperatures (below 13° C) flower abortion is high (Fahad *et al.,* 2016). When pollination fails, fruit set becomes absent, and therefore the flowers die and drop. This condition can affect other vegetables such as peppers, snap beans, and other fruiting ones. In tomatoes, flower abortion is usually preceded by the yellowing of the pedicle. Tomato flowers must be pollinated within and drop off. This is about the time it takes for the pollen to germinate and travel ups the style to fertilize the ovary at temperatures above 13°C (Fahad *et al.,* 2016). Tomatoes needs wind, humans, or insects to move the pollen from anthers to stigma if this is not possible, flower abortion occurs. Low or high nitrogen application can cause flower abortion. Also, when a tomato plant has a lot of flowers and the amount of nutrient available in the growing medium is not sufficient to support all, the plant will automatically abort some of them (Fahad *et al.,* 2016).

2.15.3 Fruit cracking

Tomato fruit crack under certain conditions. There are two different types of cracking: radial and concentric, both of which occur at the stem end. Radial cracking is more common and usually occurs during periods of high temperatures (at or above 32° C.), prolonged rain or wet soil when fruit will rapidly expand and often crack. This is particularly prevalent after a long period of dry spell. Maintaining even moisture conditions, avoiding excessive pruning, and having a heavy fruit load will help prevent this problem. Some tomato varieties are resistant to cracking and therefore varietal selection can also help approximately fifty hours of opening or they will abort alleviate this problem. Concentric cracking is also caused by rapid growth, but generally occurs when there are alternating periods of rapid growth followed by slower growth. This can occur with wet/dry cycles or cycles of high and low temperatures. Generally, this type of cracking occurs as fruits are close to maturation. Even moisture throughout the growing period will help alleviate this problem.

2.15.4 Puffiness

The general appearance of the fruit looks good but when cut there is little or no gel or seed, the fruit is nearly empty. This condition affects fruits that develop under very cool or very hot temperatures (below13° C and above 32° C.) respectively, which interferes with normal seed set (Etebu *et al.,* 2013). Tomatoes are self-pollinated but require some disturbance of the flower in order for the pollen to be shaken onto the stigma. This movement of pollen from the anther to the stigma by human through normal cultural practices like weeding, staking, pruning or even during watering and spraying. Wet, humid and cloudy weather interfere with insect's pollination so pollen may not be shaded well. Low temperatures will slow the growth of pollen tubes but excess nitrogen can also influence this condition.

2.15.5 Some common diseases of tomato

Plant diseases are one of the most important limiting factors to tomato production (Hanssen et al., 201 0). The hot, humid climate coupled with frequent rainfall and mild winters favor the development of many disease pathogens that cause diseases.

2.15.5.1 Some common bacterial diseases of tomato

2.15.5.2. Bacterial spot

Bacterial spot is the most common and often the most serious disease affecting tomatoes. This disease is caused by the bacterium Xanthomonas axonopodispv. vesicatoria. Bacterial spot lesions can be observed on leaves stems and fruit and occur during all stages of plant growth. Leaf lesions usually begin as small water-soaked lesions that gradually become necrotic and brown in the center (Hanssen *et al.,* 2010). During wet periods the lesions appear more water-soaked. Lesions generally appear sunken on the upper surface and raised on the lower surface of infected leaves. During periods of favorable weather, spots can coalesce and cause large areas of leave to lose their green pigmentation resulting in premature leave dropping. The bacterium is primarily seed-borne and most epidemics can be traced back directly or indirectly to an infected seed source. I infected seedlings carry the disease to the field, where it spreads rapidly during warm, wet weather. Workers working in wet fields can also be a major source of disease spread. Prevention is the best method for suppressing losses to bacterial spot.

Purchase seed from companies that produce the seed in areas where the disease is not known to occur. Hot water seed treatment can also be used, and tomato seed can be soaked in water that is 50° C for 25 minutes to kill the bacterium. Unlike pepper, tomatoes have no commercially available cultivars resistant to bacterial spot. Rotate away from fields where tomatoes have been grown within the past year and use practices that destroy volunteer plants that could allow the disease to be carried over to a subsequent crop. Copper fungicides used in conjunction with Maneb will suppress disease losses if applied on a preventive schedule with a sprayer that gives adequate coverage.

2.15.5.3 Bacterial wilt

Bacterial wilt, caused by Ralstonia solanacearum, is a devastating bacterial disease of tomatoes worldwide. This bacterium can last in the soil for several years and has been responsible for taking whole fields out of production. Bacterial wilt is recognized by a rapid wilting of the tomato plant, often while the plant is still green. Wilted plants will eventually die. A quick diagnostic tool is to cut a lower stem of a suspected infected plant and place it 1 2 in a clear vial or glass of water and watch for the opaque, milky bacterial streaming that comes from the cut area. Bacterial wilt is not easily controlled by fumigation or chemical means. There are few commercially available cultivars with resistance to bacterial wilt. The best control tool is to rotate away from infested fields for several years.

2.15.5.4 Bacterial speck

Bacterial speck, caused by Pseudomonas syringae pv. Leaflet lesions are very small, round and dark brown to black. During favorable weather conditions the lesions can coalesce and kill larger areas of leaf tissue. Bacterial speck causes oval to elongated lesions on stems and petioles. Tomato fruit may have minute specks with a greener area surrounding the speck. Control measures are similar to bacterial spot.

2.15.5.5 Common virus diseases of tomato

Virus diseases have been a severe limiting factor in tomato production. Most virus diseases cause stunting, leaf distortion, mosaic leaf discoloration, and spots or discoloration on fruit. The distribution of virus-infected plants is usually random with symptomatic plants often bordered on either side by healthy, non-symptomatic plants. Virus diseases are almost always transmitted by insect vectors, and the severity of a virus disease is usually tied to the rise and fall in the populations of these vectors from season to season and within a given season.

2.15.5.6 Tomato spotted wilt virus

It is one of the most common viruses affecting tomato. This virus is transmitted by thrips and can affect tomato at any stage of development. The extensive host range of TSWV in weeds allows for a continual source of inoculums for infection. As with any virus disease, however, early infections tend to cause more yield losses than those occurring later in plants' development. TSWV causes plant stunting, ring spots and bronzing on infected plants. Tomato fruit produced on infected plants may be misshapen, have dark streaks or have chlorotic spots.

2.15.5.7 Cucumber mosaic virus

It is a very common disease of tomato and can be very devastating where it occurs. This virus is transmitted by aphids and can be maintained in several weed species that surround production fields. The characteristic symptoms for CMV are severely stunted, distorted and strapped (faciated) leaves, stems and petioles. Symptoms of CMV often resemble herbicide injury. Few options are available for suppressing losses to CMV, but destruction of weed hosts that harbor the virus will help in suppressing disease spread.

2.15.5.8 Tomato yellow leaf curl virus

It is a very serious virus disease that is transmitted by whitefly, the disease is higher in times when the white fly population is also high. The affected plants are normally stunted with little or no fruit, with few chlorosis leaves.

2.15.6 Some common fungal diseases of tomato

2.15.6.1 Early blight

It is caused by *Alternaria solani* is perhaps the most common fungal disease of tomato foliage. Leaf symptoms appear as round to oblong, dark brown lesions with distinct concentric rings within the lesion. Lesions are generally surrounded or associated with a bright yellow chlorosis. Stem lesions are slightly sunken, brown and elongated with very pronounced concentric rings. Fruit may become infected around the calyx, and a velvety spore mass can often be observed on fruit lesions. The disease is introduced by wind or rain splash and is carried over to subsequent crops on infested debris. Wet, humid weather favors disease development and the fungus spores are spread mainly by wind. Unless controlled, it causes severe defoliation. Resistant varieties are available to avoid losses to early blight. Rotation and deep turning are important for reducing initial inoculums.

2.15.6.2 Late blight

It is caused by *Phytopthorainfestans* is probably one of the best-known tomato diseases worldwide. This disease causes dark, water-soaked, greasy lesions on stems and foliage. A whitish-gray, fuzzy sporulation can be seen on the undersides of leaf lesions and directly on stem lesions during periods of high moisture. A soft rot of fruit can also be observed. Warm days and cool nights coupled with adequate moisture favour the spread and infection of the late blight pathogen. Plant resistance to this disease is available but does not play a major role in disease control. Destroying plant debris and rotating away from fields with a history of the disease is necessary for the control of this disease. Preventive fungicide sprays are generally effective, especially when the disease is endemic.

2.15.6.3 Fusarium wilt

It is caused by Fusarium *oxysporum f.*sp. lycopersici. is a soil borne disease of tomatoes that is generally a problem in specific fields where the pathogen has been introduced. The disease is initially brought into a field on infested seed, plant stakes, transplants or infested soil on equipment. Symptoms usually appear during hot weather and after fruit set has begun. Symptoms appear as a yellowing and wilting on one side of the plant at first, usually during the hottest part of the day, followed by the eventual complete yellowing and wilting of the plant and the entire plant will. Vascular discolouration is often observed on stems above the ground. This fungus can stay in the soil in a resting state for several years, and rotation away from these fields for 5-7 years will lessen the severity but will not completely eliminate the disease. Fumigation really only delays disease onset and may lessen the total disease incidence. Preventing the disease from getting into the field is the best control measure, followed by the use of resistant varieties.

2.15.6.4 Nematodes

Root-knot nematodes (*Meloidogyne* spp) can cause serious economic damage to tomatoes. They live in the soil and feed on the roots of tomato forming knots that blocks water and nutrient from passing through the root system to other parts of the plant and also allow the establishment of other disease. Plants affected by the root knot nematodes are stunted in growth with pale green to light yellow leaves. The most effective way of control is by avoiding the infected area completely, or treat infected area with chemical nematicides before tomatoes are planted.

2.15.7 Some common insect pests of tomato

Insect pests can cause damage tomato plant throughout the growing season, but severity varies with location and time of year. While many insects that feed on tomato are only occasional pests a few species are common and occur every season. The severity of damage depends on the insect population and the environmental factors.

With most insects, outbreaks are difficult to predict, and it is even more difficult to predict if control measures will be required. Research has shown that the ability of a crop plant to resist or tolerate insect pests and diseases is tied to optimal physical, chemical and mainly biological properties of the soil (Altieri *et al.,* 2012). Reduced susceptibility to pest may be a reflection of differences in plant health, as mediated by soil fertility (Sarwar, 2011). Soil fertility practices can impact the physiological susceptibility of crops to insect pest by either affecting the resistance of individual plant to attack or by altering plant acceptability to certain herbivores (Altieri *et al.,* 2012). Many workers had amply illustrated the increased susceptibility effect of N-fertilization to insect infestation. Altieri *et al.* (2012) reported that many of the factors influencing susceptibility to pest and diseases do so through their effects on plant N-metabolism.

Frequent or scheduled spraying is necessary for insect management because a variety of insects attack tomato. Scouting two to three times per week, however, allowing for early detection of infestations and timely application of pest specific control measures, is the most cost-effective management strategy.

2.15.7.1 Thrips

They may be present in tomato fields throughout the growing season, but they are more common during the rains. Prior to plants blooming, tobacco thrips generally dominates the population since this species readily feeds and reproduces on foliage. Flower thrips species populations can increase dramatically once blooming and pollen availability increases. Plant injury is caused by both nymphs and adults puncturing leaf and floral tissues and then sucking the exuding sap. This causes reddish, grey or silvery speckled areas on the leaves. With severe infestations, these areas can interfere with photosynthesis and result in retarded growth. Heavy infestations during the bloom stage may cause damage to developing fruit through egg laying. This damage appears as dimples with necrotic spots in the centre and may be surrounded by a halo of discoloured tissue. To prevent direct damage, apply insecticides when twenty percent (20%) of plants show signs of thrips damage, or when five (5) or more thrips per bloom are found.

2.15.7.2 Aphids

Aphids or plant lice are small, soft-bodied insects that may feed on tomato plants from time of planting until last harvest. Aphids cluster in shaded places on leaves, stems and blossoms while winged migrants move from field to field spreading virus diseases. Large populations of aphids on young plants can cause wilting and stunting but rarely occur. At harvest, infestations can represent a contamination both through their presence and through production of honeydew, which gives rise to sooty mold.

2.15.7.3 Leaf miners

Adult leaf miners are tiny, shiny, black flies with yellow markings. Adult female flies lay eggs within the leaves, and white to pale yellow larvae with black mouthparts mine between the upper and lower leaf surface for about 5 to 7 days before dropping to the ground to pupate (Hering, 2013). The leaves are greatly weakened and the mines may serve as points where decay and disease may begin. With severe infestations, heavy leaf loss may lead to sun scald of fruit (Hering, 2013). Several parasites attack this pest and can keep leaf-miner populations under control. Leaf miners rarely pose a serious threat to tomato production except in fields where their natural enemies are reduced by early, repeated insecticide applications (Hering, 2013).

2.15.7.4 Spider mites

Spider mites appear to be developing into a more consistent pest in Solanaceae family. They generally feed on the underside of leaves, but can cover the entire leaf surface when populations are high. The minute eight-legged mites appear as tiny, reddish, greenish or yellow moving dots on the undersides of leaves. Because of their size, the first detection of spider mite infestations is usually their damage to the leaves. Leaves of tomato plants infested with spider mites are initially lightly stippled with pale blotches. In heavy infestations, the entire leaf appears light in colour and dries up, often turning reddish brown in blotches or around the edge and may be covered with webbing (Hering, 2013).

2.15.7.5 Whiteflies

Adult whiteflies are tiny (about ⅛ inch) insects with white wings, a yellow body and piercing-sucking mouthparts. Adults are found on the underside of leaves, where they feed and lay eggs. While adults can cause direct damage by feeding, typically the nymphs are the more damaging stage. Whiteflies, particularly the sweet potato or silver leaf whitefly, can be a severe pest in tomatoes grown in the cool season. At much lower densities, however, this pest causes irregular ripening of fruit and can transmit severe viral diseases, including tomato yellow leaf curl (Hering, 2013). Preventive treatments with systemic soil-applied insecticides which may require additional foliar treatments are effective in the control of whiteflies.

2.15.8 Weeds

Weed control is an important cultural practice which can increase production and productivity. Weeds compete with plant for sunlight, mineral nutrients, water and space. Weeds harbor pest and even contaminate the produce during harvesting. If weeds are not carefully control, it can lead to low yield (McErlich&Boydston, 2014). The effective way of weed control is the planting of healthy and vigorous seedlings that can grow faster than the weeds and form canopy to suppress their growth (McErlich&Boydston, 2014).

2.15.9 Effects of staking and spacing on tomatoes production

Staking is the support provided to plants with sturdy material to keep the fruits and foliage off the ground. Staking increases fruit yield, reduces the proportion of unmarketable fruit, enhances the production of high-quality fruits, prevent disease and fruit rot, allows better aeration and better exposure of the foliage to sunlight and photosynthetic activities (Alam*et al.,* 2016). Alam*et al.,* (2016) recommended staking of crops for higher yield, quality fruits, easy harvesting, and exposure of leaves for effective light interception.

According to Kwapata (1990) staking modifies the soil moisture; air temperature, radiation and evapo-transpiration, an effect which lowers the incidence of tomato diseases. In addition, staking exposes the leaves to the sun and thus increases plant photosynthetic efficiency leading to higher tomato yield compared to unstaked. Although there are many reports on the effect of staking and mulching on tomato yield (Quinn, 1974), very few studies have addressed the effect of staking and mulching on 'the development of tomato diseases. Staking significantly reduced the severity of blight (Quinn, 1974), however, Patterson (1990) reported that staking reduced the initiation of early blight in tomato.

However, influence of different plant spacing on the growth and yield of tomato plants is an important component for healthy productive plants. The correct tomato plant spacing is dependent upon which variety of tomato is being grown. The effect of plant spacing can be verified in terms of exposure to light, with narrower plant spacing there is greater overlap and shading of leaves, reduced penetration of solar radiation to basal leaves and hence higher competition of light, reducing photosynthetic efficiency of the plant. The competition for light promoted increased energy expenditure in processes of cell growth and reduced translocation of sugars for fruit (Prajapati & Modi, 2012). Plant spacing is one of the agronomic factors which significantly affect tomato production. Optimum plant spacing enhances better utilization of spaces, high yield, and quality production (Ara *et al*, 2007).

Abrha e*t al*. (2015).reported that the interaction effect of inter- and intra row spacing significantly affects both marketable and unmarketable yield of tomato. In Ethiopia, 10 to 50 cm intra row spacing and 60 to 120 cm inter row spacing were reported for different tomato varieties in different location and years (Abrha e*t al*., 2015).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental site and Location

The study was conducted at the research station of the CSIR-Crops Research Institute (CRI), Kwadaso – Kumasi, between August and November, 2020. The research field falls within the semi-deciduous rain forest zone and is characterized by a bimodal rainfall pattern, from April to July and September to December, with an average annual rainfall of 1500 mm. The soil is Ferric Acrisol (FAO/UNESCO legend, 1986). Total rainfall and mean sunshine recorded for CSIR – CRI, Kwadaso during period of the experiment was 531.1mm and 30.4h respectively. Maximum and minimum mean temperatures were however, 32.7˚C and 22.7˚C respectively. Kwadaso station lies between latitude 06, 42˚ North and longitude 001, 4˚ West.

3.2 Soil type and vegetation at the experimental site

The soil at the experimental site is derived from the voltain sandstone of Afram plains. It belongs to the savannah ochrosol class and is characterized by deep sandy loam; free from pebbles. It is well drained and contains moderate organic matter. The soil has a good water holding capacity. It has been classified by FAO/UNESCO (2008) legend as chromic luvisol and locally as Bediesi series.

3.3 Experimental Design, Treatments and Field layout

3.3.1 Experimental Design

The experimental design used for the study was 2 x 3 factorial arranged in Randomized Complete Block Design (RCBD) with three replications. The treatment wasmade up of three plants spacing 50cm x 40 cm, 60 cm x 40 cm, 70 cm x 40 cm and two factors staked, and non-staked). Each treatment was replicated three times.

There were six experimental plots with varying plot length of which each block contained six plots.

3.3.2Treatment

Table 3.1: Treatment combinations

Treatments	Plant spacing	Staking
T1	50 cm x 40 cm	Staking
T2	60 cm x 40 cm	Non staking
T3	70 cm x 40 cm	Staking
T4	50 cm x 40 cm	Non staking
T5	60 cm x 40 cm	Staking
T6	70 cm x 40 cm	Non staking

3.3.3Field layout

The total field size of 13.4 m x 11 m (1474 m^2) was demarcated, cleared, lined and pegged and ridges was prepared. Each experimental plot measured 2m, 4.8m and 5.6 m x 3m respectively based on the respective treatment. A 2.0 m was left between blocks. Field layout is indicated in Figure 3.1.

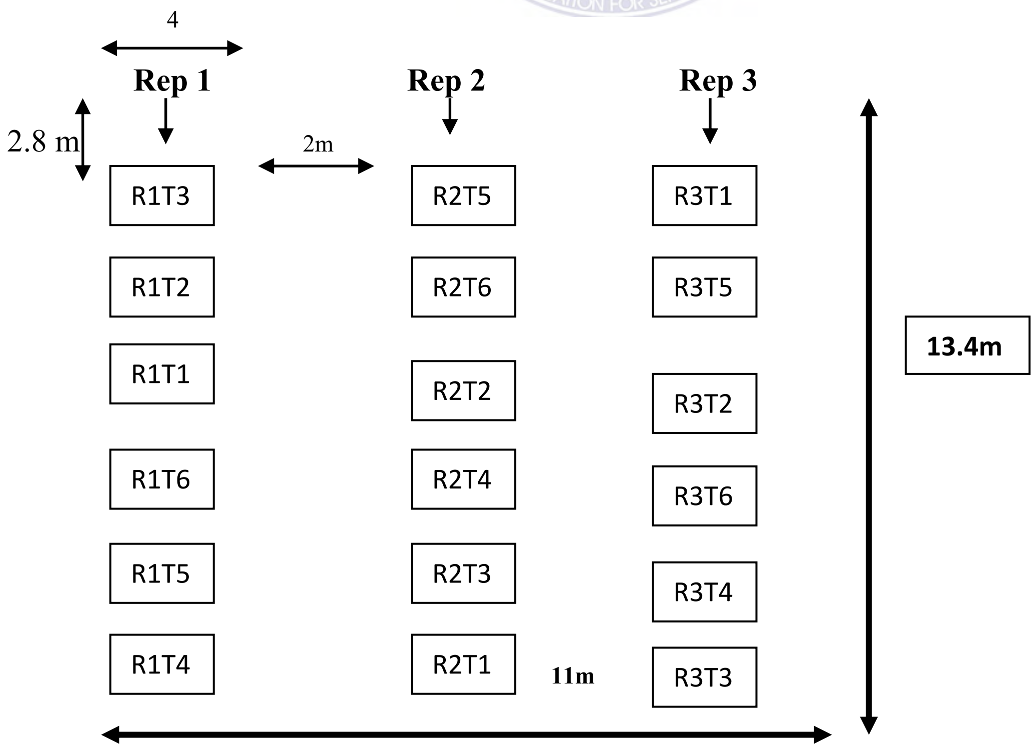

Figure 3.1 Field layout not drawn to scale

3.4 Planting material and Nursery

Seeds of the tomato genotype SHASTA were raised under greenhouse conditions. The variety was considered because of its strong plant with good field stand, mid-early maturity yielding uniform round fruit and its ability to withstand cracking. The variety was obtained from the CRI Research Station, Kwadaso. Plastic seed trays consisting of 90 cells each were filled with potting soil as growth medium to raise the seedlings. The potting soil was first mixed with water and vigorously stirred to make it lose before it was used. The seeds were drilled to the depth of about 0.5 – 10cm in each cell and gently watered after sowing.

In all seven trays were used for the nursery. Watering of seedlings was subsequently done on daily basis by the use of watering can.

3.5 Land preparation

The land was ploughed by a tractor to remove the stumps. Hoeing and raking was carried out to obtain a level ground. Lining and pegging were also carried out to obtain the required plot size.

3.6 Transplanting

Twenty-one-days old healthy seedlings of genotype Shasta tomato was transplanted on to the experimental site. Almost all the transplanted seedlings had about 4-6 leaves and their average plant height ranges 9-12 cm. The seedlings were watered before they were removed from their seed trays to the field. Watering was carried out immediately after transplanting to prevent stress of seedlings. Seedlings were sprayed with fungicide, Mancozep 80 WP (Mancozeb dithiocarbonate) at a rate of 10g per litre of water to prevent fungal infection. Spraying was then repeated on the 12 and 17 days. When the seedlings reach seven (7) days old, the fungicide, Mancozep 80 WP

(Mancozeb dithiocarbonate) at 10 g per litre of water was sprayed on seedlings to control fungal infection, especially damping off. This was repeated at days 12 and 17 before the healthy and uniform seedlings transplanted to the experimental site when they are 21days old. The seedlings were supplied with N.P.K (15:15:15) nutrient solution. The nutrient solution was prepared using 1g/litre N.P.K (15:15:15) at a concentration of 0.5% in order for seedlings to get good rooting as well as growth.

3.7 Cultural Practices

3.7.1 Weed control

Weeding was done manually in one form by using a hoe. The first weeding was done on two weeks after seedling transplanted. The second weeding was done continuous as the weed grows using a hoe and also just before a thesis. This was to ensure that weeds did not compete with the crops for nutrients and water. Hand weeding, pulling of weeds was done continuously and on two weeks' interval.

3.7.2 Staking and Pruning

Staking was done two weeks after transplanting as plant lodges from fruit setting, it requires proper staking with the help of bamboo sticks and tread. Depending on the type of variety (indeterminate) keep the height of bamboo and tread support. To control the vegetative growth, and size, it is necessary to prune the tomato plant. Stem pruning is recommended. Pruning was done removing excess branches from the main stem just below the first flower twig to allow only 3-4 stems to grow and prune the other side branches, by using a sharp knife.

3.7.3Pest and Disease control

Golan 250 ml bottle, a systemic broad-spectrum insecticide was used to prevent aphid, white fly, caterpillar, thrips, leaf miner or mealy bug. 30 ml of Golan was mixed in 15L of water and was applied to crops every 2 weeks. Top Cop with Sulphur (1 Litre), 150-300 ml of Top Cop (active ingredient: Copper Sulphate Tribasic) with Sulphur was put in a Knapsack sprayer and was sprayed on crops when any whitefly was detected on the tomato fruit. This was repeated every two weeks but was stopped when the fruits had attained ripening.

3.7.4 Fertilizer application

NPK (15-15-15) fertilizer was applied at 220kg/ha at two weeks after transplanting.

3.7.5 Irrigation

Due to erratic rain fall, supplementary irrigation was carried out as and when the need arise since cowpea is a rain fed crop. Subsequent watering was also done every other day in the morning using water holes and watering cans. Each plant was given equal amount of water.

3.8 Data Collection and Statistical Analysis

Data were collected on phenology, vegetative growth, yield and yield components. The following records were taken;

3.9. Phenological Data

3.9.1 Percentage plant establishment

The percentage plant establishment was measured by counting the number of plants that had established at twenty-one (21) days after planting and the percentage plant establishment subsequently estimated.

3.9.2 Days to 50% flowering

This was determined as the number of days when half of plants within the two harvestable central rows had flowered from the day of transplanting of seedlings.

3.9.3 Days to fruiting

Through field monitoring and observation, number of days to 50% fruiting taken within the harvestable middle row was counted.

3.9.4 Vegetative Growth

3.9.4.1 Plant height (cm)

The plant height was measured from soil surface to tip of the plant at vegetative and reproductive stages using a metric rule. Thus, the ruler was placed at the base of the plant to epical leaf of the experimental plant. The mean plant height per treatment was computed.

3.9.4.2Stem diameter (cm)

Stem diameter was determined using the vernier caliper to measure the widest part of the tagged plant from the two central rows from 30 days after transplanting and atevery 14 days' intervals and the mean was recorded.

3.9.4..3 Canopy width per plant (cm)

The total canopy spread per plant was counted separately from the four (4) tagged plants at from two middle row 30 days after planting and every at every 14-day intervals the recorded.

3.9.4.4 Number of branches

The total number of branches per plant was counted from each six (6) tagged plants randomly selected from the two-middle row per plot 30 days after transplanting and at every two weeks' interval and the mean estimated.

3.10 Yield and Yield components

3.10.1 Fruit Weight (kg)

The Fruit Weight per plot from the central rows was weigh with an electric scale and the mean computed and recorded.

3.10.2 Number of fruits per plot

The total number of fruits was counted per plant and the mean was computed.

3.10.3 Yield/hectare

The mean fruit weight for each of the six record plants was used to calculate yield per hectare. This was expressed as:

$$\text{Yield/hectare} = \left(\frac{\text{Fruit yield per plot}}{\text{Plot size}}\right) \times 10{,}000m^2$$

3.11 Statistical Analysis

The data collected in this study were subjected to statistical analysis. The analysis of variance (ANOVA) was carried out using Genstat statistical package (2007) version of 9.2. Significant differences between treatment means were delineated by Least Significance Difference (LSD) test at 5% level of probability.

CHAPTER FOUR

4.0 RESULTS

4.1 Phonological Growth

4.1.1 Percentage Plant Establishment

There was no significant ($p \geq 0.05$) difference between staking, spacing and staking × spacing interaction in Percentage plant establishment. However, 50 cm x 40 cm and 60 cm x 40 cm had the same percentage plant establishment (60.0 %) (Table 4.1).

4.1.2 Days to 50 % Flowering

There was no significant ($p \geq 0.05$) difference between staking, spacing and staking × spacing interaction in days to 50 % flowering although the interaction between No staking × 60 cm x 40 cm and No staking × 70 cm x 40 cm was late to flower (34.0 days) whilst staking × 50 cm x 40 cm interaction was earliest to flower with mean value of (30.0 days) (Table 4.1).

4.1.3 Days to Fruiting

There was no significant ($p \geq 0.05$) difference between staking, spacing and staking × spacing interaction in days to fruiting (Table 4.1). Spacing 60 cm x 40 cm and staking × 60 cm x 40 cm interaction produced the same days to fruiting (Table 4.1).

Table 4.1: Percentage plant establishment, days to 50 % flowering and days to fruiting as influenced by staking and spacing

Treatment	Levels	% Plant establishment	Days to 50% flowering	Days to fruiting
Staking	No staking	58.3	33.1	48.0
	Staking	61.1	31.1	46.9
LSD (P ≤ 0.05)		NS	NS	NS
Treatment	Levels	% Plant establishment	Days to 50% flowering	Days to fruiting
Spacing	50 cm x 40 cm	60.4	30.6	45.5
	60 cm x 40 cm	60.4	33.1	51.0
	70 cm x 40 cm	58.3	32.5	45.8
LSD (P ≤ 0.05)		NS	NS	NS
Interaction	No staking x 50 cm x 40 cm	58.3	31.3	48.3
Staking x Spacing	No staking x 60 cm x 40 cm	60.4	34.0	50.7
	No staking x 70 cm x 40 cm	56.3	34.0	45.0
	Staking x 50 cm x 40 cm	62.5	30.0	42.7
	Staking x 60 cm x 40 cm	60.4	32.3	51.3
	Staking x 70 cm x 40 cm	60.4	31.0	46.7
LSD (P ≤ 0.05)		NS	NS	NS
CV(%)		7.3	9.4	9.9

*** DAP – Days after planting**

4.2 Vegetative Growth

4.2.1 Plant Height (cm)

There was no significant ($p \geq 0.05$) difference between variety in plant height from 28 DAT to 42 DAT (Table 4.2). However, a significant ($p \leq 0.05$) difference exist between staking from 56 DAT to 84 DAT in plant height (Table 4.2). There was no significant ($p \leq 0.05$) difference spacing in plant height from 28 DAT to 84 DAP except at 56 DAT in which significant difference exist in plant height. There was no significant ($p \geq 0.05$) difference between Staking × spacing interaction in plant height from 30 DAP to 86 DAT except at 58 DAT where the interaction between staking × 70 cm × 40 cm differed significantly from Staking × 50 cm × 40 cm in plant height (Table 4.2).

Table 4.2: Plant height of tomatoes as influenced by staking and spacing from 28 DAT to 84 DAP

Treatment	Levels	Plant height (cm)				
		28 DAT	42 DAT	56 DAT	70 DAT	84 DAT
Staking	No staking	24.6	35.5	44.7	48.2	53.6
	Staking	20.5	39.0	57.4	62.4	64.8
LSD ($P \leq 0.05$)		NS	NS	6.20	5.05	5.40
Spacing	50 cm x 40 cm	22.5	35.3	54.8	56.4	59.6
	60 cm x 40 cm	25.7	37.0	44.6	52.6	58.1
	70 cm x 40 cm	19.5	39.6	53.8	56.9	59.8
LSD ($P \leq 0.05$)		NS	NS	7.59	NS	NS
Interaction	No staking x 50 cm x 40 cm	25.4	32.9	48.1	49.5	52.5
Staking x Spacing	No staking x 60 cm x 40 cm	29.9	35.4	39.9	46.3	55.7
	No staking x 70 cm x 40 cm	18.3	38.3	46.1	48.8	52.6
	Staking x 50 cm x 40 cm	19.5	37.6	61.4	63.2	66.7
	Staking x 60 cm x 40 cm	21.5	38.6	49.3	58.8	60.5
	Staking x 70 cm x 40 cm	20.6	40.9	61.5	65.0	67.1
LSD ($P \leq 0.05$)		NS	NS	10.73	NS	NS
CV (%)		29.0	21.0	18.5	15.7	13.1

4.2.2 Number of branches per plant

There was no significant (p ≥ 0.05) difference between No staking and staking in number of branches per plant although difference exist between treatment from 30 to 42 and at 84 DAT. However, a significant difference exists between treatment at 56 DAP to 70 DAT (Table 4.3). Staking produced significantly more branches than No staking from 28 to 84 DAT whilst staking had the least in plant height at the same period. There was no significant (p ≥ 0.05) difference spacing in number of branches per plant from 30 DAP to 86 DAP except from 56 DAP to 84 DAP which 70 cm × 40 cm differed significantly in number of branches per plant. There was no significant (p ≥ 0.05) difference between staking ×spacing interaction in number of branches per plant at 28 DAP to 84 DAP except from 56 to 84 DAT in which the interaction between No staking × 70 cm × 40 cm differed significantly from other treatments in number of branches per plant during the growing period (Table **4.3).**

Table 4.3: Number of branches of tomatoes as influenced by staking and spacing from 28 DAT to 84 DAP

Treatment	Levels	Number of branches				
		28 DAT	42 DAT	56 DAT	70 DAT	84 DAT
Staking	No staking	8.6	11.4	15.0	16.6	18.2
	Staking	8.3	12.8	17.3	18.6	20.2
LSD (P ≤ 0.05)		NS	NS	1.47	1.83	NS
Spacing	50 cm x 40 cm	8.5	11.7	14.9	16.4	17.8
	60 cm x 40 cm	8.8	12.5	14.9	15.9	17.3
	70 cm x 40 cm	8.1	12.1	18.6	20.5	22.5
LSD (P ≤ 0.05)		NS	NS	1.80	2.25	2.74
Interaction						
Staking x Spacing	No staking x 50 cm x 40 cm	8.5	10.1	10.8	12.0	14.0
	No staking x 60 cm x 40 cm	9.3	12.3	13.4	14.1	16.4
	No staking x 70 cm x 40 cm	8.1	12.0	20.7	23.6	24.1
	Staking x 50 cm x 40 cm	8.5	13.3	19.1	20.8	21.6
	Staking x 60 cm x 40 cm	8.3	12.7	16.3	17.7	18.1
	Staking x 70 cm x 40 cm	8.2	12.3	16.4	17.4	20.9
LSD (P ≤ 0.05)		NS	NS	2.55	3.18	3.87
CV (%)		9.4	12.1	23.9	24.4	21.2

4.2.3 Canopy width

There was a significant (P ≥ 0.05) difference between No staking, staking, spacing and staking × spacing interaction in number of canopy width from 30 to 84 DAT (Table 4.4) However, no significant difference (P ≥ 0.05) exists between treatment at 56 DAP to 70 DAT during the growing period (Table 4.4).No staking × 50 cm 40 cm produced significantly higher 42 DAT from to 70 DAT than other treatments (Table 4.4).

Table 4.4: Canopy width of tomatoes as influenced by staking and spacing from 28 DAT to 84 DAP

Treatment	Levels	Canopy width (cm)				
		28 DAT	42 DAT	56 DAT	70 DAT	84 DAT
Staking	No staking	33.3	39.2	43.7	45.6	48.3
	Staking	22.4	30.9	43.3	43.8	44.6
LSD (P ≤ 0.05)		4.85	3.04	NS	NS	2.75
Spacing	50 cm x 40 cm	31.5	36.4	44.8	45.3	46.6
	60 cm x 40 cm	29.3	36.8	43.9	45.6	48.6
	70 cm x 40 cm	22.7	32.0	41.8	43.2	44.1
LSD (P ≤ 0.05)		5.94	3.72	NS	NS	3.37
Interaction						
Staking x Spacing	No staking x 50 cm x 40 cm	41.3	44.7	46.8	47.5	49.4
	No staking x 60 cm x 40 cm	35.4	41.7	43.8	46.5	51.7
	No staking x 70 cm x 40 cm	23.1	31.2	40.6	42.9	43.7
	Staking x 50 cm x 40 cm	21.8	28.1	42.8	43.1	43.8
	Staking x 60 cm x 40 cm	23.2	32.0	44.0	44.8	45.4
	Staking x 70 cm x 40 cm	22.3	32.7	42.9	43.4	44.5
LSD (P ≤ 0.05)		8.41	5.26	NS	NS	4.77
CV (%)		5.5.3	6.8.7	6.5	5.4	8.0

4.2.4 Stem diameter

There was no significant (P ≥ 0.05) difference between No staking, spacing and staking × spacing interaction in stem diameter from 42 to 84 DAP except at 28 where no significant difference exists between treatment stem diameter. At 28 DAT No staking and staking produced the same mean value (0.61) (Table 4.5).

Table 4.5: Stem diameter of tomatoes as influenced by staking and spacing from 28 DAT to 84 DAP

Treatment	Levels	Stem diameter (cm)				
		28 DAT	42 DAT	56 DAT	70 DAT	84 DAT
Staking	No staking	0.61	0.94	1.32	1.61	2.07
	Staking	0.61	0.86	0.95	1.26	1.61
LSD (P ≤ 0.05)		NS	NS	NS	NS	NS
Spacing	50 cm x 40 cm	0.72	0.99	1.14	1.32	1.84
	60 cm x 40 cm	0.66	1.01	1.21	1.57	1.93
	70 cm x 40 cm	0.44	0.70	1.05	1.42	1.75
LSD (P ≤ 0.05)		0.13	NS	NS	NS	NS
Interaction						
Staking x Spacing	No staking x 50 cm x 40 cm	0.44	1.01	1.40	1.60	2.18
	No staking x 60 cm x 40 cm	0.88	1.20	1.43	1.73	2.03
	No staking x 70 cm x 40 cm	0.50	0.60	1.13	1.50	2.00
	Staking x 50 cm x 40 cm	1.01	0.96	0.87	1.04	1.49
	Staking x 60 cm x 40 cm	0.44	0.81	1.00	1.41	1.83
	Staking x 70 cm x 40 cm	0.38	0.80	0.97	1.34	1.51
LSD (P ≤ 0.05)		0.18	NS	NS	NS	NS
CV (%)		13.5	18.3	16.1	16.7	17.7

4.3 Yield and yield components

4.3.1 Number of plants harvested

Result from (Table 4.6) indicates that there was no significant ($P \geq 0.05$) difference between staking, spacing, staking × spacing interaction in number of plants harvested although difference exist between treatment. No staking, spacing 60 cm × 40 cm and interaction No staking 50 cm × 40 cm, No staking 60 cm × 40 cm and staking 70 cm × 40 cm recorded the same mean value respectively (9.0 and 9.3).

4.3.2 Number of fruits per plant

There was no significant ($P \geq 0.05$) difference between staking, spacing and staking ×spacing interaction in number of fruits per plant although staking 60 cm × 40 cm, staking 70 cm × 40 cm, No staking 60 cm × 40 cm and staking 60 cm × 40 cm recorded the same mean value of (13.3 and 15.0) (Table 4.6).

4.3.3 Fruit diameter

There was no significant ($P \geq 0.05$) difference between staking, spacing and staking ×spacing interaction in fruit diameter although difference exist between treatment with, No staking 70 cm × 40 cm recording the highest (4.35) fruit diameter (Table 4.6).

4.3.4 Fruit length (cm)

Result from (Table 4.6) indicates that staking, spacing and staking ×spacing interaction were not significant in fruit length although the interaction between staking 70 cm × 40 cm, No staking 70 cm × 40 cm and70 cm × 40 cm recorded the same mean value (7.3) in fruit length.

Table 4.6: Number of plants harvested, number of fruits per plant, fruit diameter and fruit length (cm) as influenced by staking and spacing

Treatment	Levels	Number of plants harvested	Number of fruits per plant	Fruit diameter (cm)	Fruit length (cm)
	No staking	9.0	18.1	4.20	7.0
	Staking	9.2	13.9	4.14	7.1
LSD (P ≤ 0.05)		NS	NS	NS	NS
Spacing	50 cm x 40 cm	9.5	19.8	4.14	7.2
	60 cm x 40 cm	9.0	14.2	4.18	6.6
	70 cm x 40 cm	8.8	14.0	4.20	7.3
LSD (P ≤ 0.05)		NS	NS	NS	NS
Interaction					
Staking x Spacing	No staking x 50 cm x 40 cm	9.3	24.7	4.13	6.9
	No staking x 60 cm x 40 cm	9.3	15.0	4.13	6.8
	No staking x 70 cm x 40 cm	8.3	14.7	4.35	7.3
	Staking x 50 cm x 40 cm	9.6	15.0	4.16	7.6
	Staking x 60 cm x 40 cm	8.6	13.3	4.23	6.4
	Staking x 70 cm x 40 cm	9.3	13.3	4.05	7.3
LSD (P ≤ 0.05)		NS	NS	NS	NS
CV (%)		8.3	13.8	11.7	11.1

4.3.4Number of fruits per plot

There no significant (P≥0.05) difference between No staking, staking and staking × spacing interaction in number of fruits per plot (Table 4.6). No staking × 70 cm x 40 cm had the highest mean value of (59.7) while staking × 50 cm x 40 cm recorded the lowest mean value of (39.0).There was a significant (P ≤ 0.05) difference between spacing 50 cm x 40 cm, 60 cm x 40 cm, and 70 cm x 40 cm number of fruit per plot. Spacing 70 cm x 40 cm differed significantly from staking and staking × spacing interaction number of fruit per plot (Table 4.7).

4.3.5 Fruit weight per plot

Result from (Table 4.7) indicates that there was a significant (P $\geq$ 0.05) difference between staking, No staking and staking × spacing interaction in fruit weight per plot. No Staking× 50 cm x 40 cm differed significantly from spacing in fruit weight per plot.50 cm x 40 cm produced significantly higher fruit weight per plot than No staking× 60 cm x 40 cm (Table 4.7). Differences exist between treatments and No Staking × 50 cm x 40 cm recorded the heaviest (1073.0 g) fruit weight per plot and the least in No Staking × 60 cm x 40 cm (300g) (Table 4.7).

4.3.6 Yield per hectare (kg)

Table 4.1 shows that there was a significant (P $\leq$ 0.05) difference between staking and No staking in yield per hectare. Staking produced significantly higher (1996.0) yield per plant than No staking treatment with the least recorded (1801.0) in yield per plant (Table 4.7).

There was a significant (P $\leq$ 0.05) difference between spacing 50 cm x 40 cm, 60 cm x 40 cm and 70 cm x 40 cm in yield per hectare. Spacing 50 cm x 40 cm produced the highest yield per hectare while 70 cm x 40 cm produced the least mean of (1318.0) (Table 4.7).

The interaction between No staking 50 cm x 40 cm differed significantly (p$\leq$0.0) from other treatment interactions (Table 4.7). Staking 60 cm x 40 cm produced significantly higher yield per hectare than 60 cm x 40 cm.

Table 4.7: Number of fruits per plot, Fruit weight per plot and Yield per hectare (kg) as influenced by staking and spacing

Treatment	Levels	Number of fruits per plot	Fruit weight per plot (g)	Yield per hectare (kg)
Staking	No staking	48.9	647.0	1801.0
	Staking	43.9	755.0	1996.0
LSD ($P \leq 0.05$)		NS	50.5	125.6
Spacing	50 cm x 40 cm	39.2	838.0	2618.0
	60 cm x 40 cm	46.7	676.0	1760.0
	70 cm x 40 cm	53.3	591.0	1318.0
LSD ($P \leq 0.05$)		8.96	61.8	153.9
Interaction				
Staking x Spacing	No staking x 50 cm x 40 cm	39.3	1073.0	3352.0
	No staking x 60 cm x 40 cm	47.7	300.0	781.0
	No staking x 70 cm x 40 cm	59.7	569.0	1270.0
	Staking x 50 cm x 40 cm	39.0	603.0	1883.0
	Staking x 60 cm x 40 cm	45.7	1051.0	2738.0
	Staking x 70 cm x 40 cm	47.0	612.0	1367.0
LSD ($P \leq 0.05$)		NS	87.4	217.6
CV (%)		11.8	14.8	14.4

CHAPTER FIVE

5.0 DISCUSSION

5.1Phenology of Tomatoes as Affected by Staking and Plant Spacing

The non -significant difference between staking, spacing and staking × spacing interaction in days to percentage plant establishment might probably be that plant spacing has no effect on staking.

The same higher mean value of (60.4 days) produced by 50 cm × 40 cm, 60 cm × 40 cm, staking × 60 cm × 40 cm, staking × 60 cm × 40 cm and No staking × 60 cm × 40 cm while No staking × 70 cm × 40 cm had least mean value (56.3 days) could be due to closer spacing. This disagrees with Winter and Ohlrogge (2013) and Scarbook and Doss (2017) who reported that plant established by increased with increasing in spacing and establishment of plant is different under different spacing depends on the interaction of genetic makeup and environment (Zhang *et al.,*2019).

The non- significant difference between staking with spacing in days to fruiting and days to 50 % flowering might be due to differences in crop response to spacing, soil nutrient and moisture. This may enhance plant with initial vigorous seedling growth, proper plant establishment and subsequently early flowering. This agrees with Yemane*et al.* (2013) that the days to fruiting and days to 50 % flowering its response to growth factors such as adequate spacing for light interception and utilization soil water as well as nutrients for plants early development in terms of flowering and fruit development. This disagrees with Kamara *et al.* (2016) that % flowering increased with increase in spacing 80 cm x 40 cm in Ghana.

5.2 Growth of Tomato as Influenced by Staking and Spacing

The significant ($p \leq 0.05$) difference between staking, spacing and staking ×spacing interaction in plant height at 56 DAT could be due to differences in genetic characteristics of variety. The non-significant difference between staking, spacing and staking ×spacing interaction in plant height at 56 DAT in plant height from 28 to 86 DAT this might due to influence in less competition of sunlight, water and natural nutrient for growth. Plant's ability to take in sufficient nutrient from the soil and also intercept solar radiation by the canopy are important determinants of growth (Raza *et al.,* 2019).

The significantly increase of number of branches per plant from 56 to 84 DAT might be due to the differences in tomato plant and it response to spacing and staking. This could lead to less competition for available space for nutrient absorption which would influence plant vegetative growth and development. This agrees with (Rafiei, 2019) that for most crops, spacing and staking has a major influence on number of branches. Tomato may promote vegetative growth and also efficiently utilize the solar radiation to enhance photosynthesis as well as root growth for exploitation of soil moisture. This corroborates with the findings of (Loic*et al.,* 2018) that spacing and staking has a major influence on crop branches and economic profitability.

The significant difference between staking, spacing and staking × spacing in canopy width could be due to competition for soil nutrient and solar radiation. Tomato displays morphological adaptations to its growth environment, by modifying its canopy structure in response to staking (Huang *et al.,* 2017). The greater number of canopy width produced by No staking × 50 cm × 40 cm and compared to No staking × 50 cm × 40 cm and staking × 60 cm × 40 cm could be due to efficient use of soil nutrients for early growth with subsequent high light interception. Plant canopy determines solar radiation interception and utilization and may impact positively on yield (Deng *et al.,* 2015).

The significant ($P \geq 0.05$) difference between staking, spacing and staking × spacing interaction in stem diameter at 28 DAT. Stem diameter has been reported to be positively correlated with productivity of plants (Saeed *et al.,* 2011). The Stem of a plant is an important growth character directly linked with the productive potential of the plant in terms of biomas, fruit and fruit yield. Results from this study showed that non-significant ($p \geq 0.05$) difference between staking, spacing and staking × spacing interaction in stem diameter from 42 DAT to 86 DAT might be that spacing no influence on staking. This contradicts those found by (Weston, 2014) that plant spacing has a yielded advantage for early plant growth.

5.3 Yield and Yield Components of Tomato as Influenced by Staking and Spacing

The same number of plants harvested produced by staking, spacing and staking × spacing interaction in could be that treatments had no effect on number of plants harvested. The highest number of plants harvested produced by 50 cm × 40 cm could be attributed to closer spacing with initial advantage of having more plant harvested. This is in disagreement with earlier findings by Arioglu *et al.* (2017); Jaiswal *et al.* (2018) who reported that wider spacing of 80 cm x 40 cm proved superior in increasing number of plants harvested than closer spacing. Crop yield is determined by the efficiency with plant use of available environmental resources such as nutrient, light and water for growth and subsequently yield (Onat *et al.,* 2016).The non-significant ($P \geq 0.05$) difference between staking, spacing and staking × spacing interaction in number of fruits per plant could be that staking had no influence on spacing.

No staking × 50 cm × 40 cm differed significantly from those planted on staking × 60 cm × 40 cm in number of fruits per plant This might be due to closer inter row planting spacing. The closer spacing might have contributed to decreased inter specific competition for growth resources and compensated for by the increased number of cobs per plant.

The difference between 70 cm × 40 cm spacing from 50 cm x 40 cm and 60 cm × 40 cm in number of fruits per plot could be attributed to wider spacing with initial advantage of having taller plants for light interception and utilization with subsequent production of more fruit on a plant. This is in disagreement with earlier findings by Ariogluet *al.* (2017); Jaiswal *et al.* (2018) who reported that closer spacing of 50 cm x 40 cm proved superior in increasing number of fruits per plot than wider spacing. Crop yield is determined by the efficiency with plant use of available environmental resources such as nutrient, light and water for growth and subsequently yield (Onat *et al.,* 2016).

A significant ($P \leq 0.05$) difference exists between staking, spacing and staking × spacing interaction in yield per hectare. No staking × 50 cm × 40 cm recorded the maximum mean value (33352.0 kg/ha) as compared to No staking × 60 cm × 40 which produced the minimum mean value (781.0 kg/ha). This might be due to tomato plant has intercept sunlight and has the potential to transport photosynthetic materials within plants to sink (Clark *et al.,* 2000). This is similar to the findings of Gardner *et al.* (2010) who attributed yield differences and conductance value and to differences between genotypes in partitioning of photosynthetic materials towards economic yield. Spacing 50 cm x 40 cm had the highest yield compared to other spacing. This might be that treatment effect on the crop. This agrees with Olufajo (2012). However, Dawadi and Sah (2012) reported positive relationship between yield and spacing.

Huang *et al.* (2015) also recognized that the photosynthetic capacity of the plant determines the overall productivity; the extent of development of each yield character is also dependent on the interrelationship between the various yield components.

CHAPTER SIX

6.0CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The result revealed that, No staking 70 cm × 40 cm established earliest (56.3 days) whilst No staking 60 cm × 40 cm established late (60.4 days).No staking produced significantly higher number of branches per plant than other treatments from 42 to 84 days after planting (DAP).

It was also observed that staking with 50 cm × 40 cm was earliest to flower (30.0 days) whilst staking 50 cm × 40 cm was earliest to fruit (42.7 days). Staking and staking ×70 cm × 40 cm produced significantly taller plants than No staking and staking ×70 cm × 40 cm which produced shortest plants across the entire growing period.

The study further disclosed that, No staking 50cm × 40 cm produced the widest canopy from 42 DAP to 70 DAP and number of fruits per plant at harvest. No staking × 50 cm × 40 cm produced the highest yield per hectare and fruit weight per plot.50 cm × 40 cm produced fruit weight per plot and number of fruits per plant. However, No staking produced the least fruit diameter.

6.2 Recommendations

The study recommends that for higher yield per hectare, farmers are encouraged to practices staking and planted on 60 cm × 40 cm for optimum yield.

It is also recommended that farmers are encouraged to plant tomato using 50 cm × 40 cm spacing for higher number plant per plot and early days of fruiting. The work should be repeated, if possible, on farmer's field to ensure that the result is validated and to facilitate the transfer of technology.

REFERENCE

Abdel-Mawgoud N.H.M, Greadly E, Helmy Y.I, Singer S.M. (2007). Responses of tomato plants to different rates of humic-based fertilizer and NPK fertilization. *J. Appl. Sci. Res.3*(2):169-174.

Abrha,H, A. Birhanu, M. Desta, and Kebede, A. (2015). Effect of inter and intra-row spacing on yield and yield components of tomato (Solanum lycopersicumlinn.) in SouthTigray, Ethiopia," *Journal of Natural Sciences Research, vol*. 5, no. 5, pp. 1–5, 2015.

Adejuwon, J. O. (2017). An assessment of the changing pattern in tomato cultivation in Sokoto-Rima River Basin, *Nigeria. Applied Tropical Agriculture*, 22(2), 88-93.

Adimabuno, A. M. (2010). Marketing and market queens: a case of tomato farmers in the Upper East Region of Ghana. GedrucktmitGenehmigung der PhilosophischenFakultät der Rheinischen Friedrich-Wilhelms-Universität Bonn.

Adubofuor, J. E., Amankwah, A., Arthur, B. S. and Appiah, F. (2010). Comparative \study related to physico-chemical properties and sensory qualities of tomato juice and cocktail juice produced from oranges, tomatoes and carrots. *African Journal of Food Science Vol*. 4(7), pp. 427 – 433.

Aduhene-Chinbuah, J. (2018). Physiology, Growth, Yield and Fruit Quality of Selected Greenhouse Tomatoes (Solanum Lycopersicum) Varieties as Affected by Different Growing Media and Potting Bag Sizes.

Agbaglo, S. Y. (2017). Interaction of Meloidogyne Incognita and Fusarium OxysporumF.Sp. Vasinfectum Snyder and Hansen on Growth, Yield and Wilt Severity on Two Okra (*Abelmoschus Esculentus*) Varieties

(Doctoral dissertation, University of Ghana). Agriculture and Healthcare, 3 (1 0), 51 -61.

Agyekum, A. (2015). Overview of Tomato Value Chain in Ghana; A Presentation at the WACCI Tomato Value Chain Meeting, Legon, Accra.

Akoroda, M.O., Ogbechie-Odiaka N.I.,Adebayo, M. L., Ugwo, O.E.,&Fuwa, B. (1990). Flowering, pollination and fruiting in fluted pumpkin (Telferia occidentalis).*Scientia Hort.* 43:197-206

Alam, M. S., Islam, N., Ahmad, S., Hossen, M. I., & Islam, M. R. (2016). Effect of different Staking methods and stem pruning on yield and quality of summer tomato. *Bangladesh Journal of Agricultural Research,* 41 (3), 41 9-432.

Al-Hassan, R., &Diao, X. (2007). Reducing Regional Disparities in Growth and Poverty Reduction in Ghana: Policy Options and Public Investment Implications, (in) Poverty Reduction Strategy in the New Millennium: Emerging Issues, Experiences, and Lessons. China Financial Economic Press. L. Zhang and S. Fan (eds.) 221–249.

Altieri, M. A., Ponti, L., & Nicholls, C. I. (2012). Biodiversity and pest management. Biodiversity and insect pests: key issues for sustainable management, 72-84Soil fertility, biodiversity and pest

Ames, M., & Spooner, D. M. (2008). DNA from herbarium specimens settles a controversy about origins of the European potato. *American Journal of Botany*, 95(2), 252-257.

Amoah, P., Adamtey, N., &Cofie, O. (2017). Effect of urine, poultry manure, and dewatered faecal sludge on agronomic characteristics of cabbage in Accra,Ghana. Resources, 6(2), 1 9.

Animashaun, B. O., Popoola, A. R., Enikuomehin, O. A., Aiyelaagbe, I. O. O., &Imonmion, J.E. (2017). Induced resistance to fusarium wilt (Fusarium oxysporum) in tomato using plant growth activator, acibenzolar-S-methyl. *Nigerian Journal of Biotechnology,* 32(1),83-90.

Ara. N, M. Bashar, S. Begum, and Kakon ,S. (2007) .Effect of spacing and stem pruning on the growth and yield of tomato," *International Journal of Sustainable Crop Production,* vol. 2, no. 3, pp. 35–39, 2007.

Archontoulis, S. V., Struik, P. C., &Danalatos, N. G. (2005). Leaf photosynthesis of kenaf

Arioglu, T, F, Sowley, E. N. K., &Damba, Y. (2017). Influence of staking on growth and yield of tomato in the Guinea Savannah Zone of Ghana. *International J of Scientific & Technology Research*, *2*(12), 103-107.

Ashby, H. (2000). Protecting Perishable Foods during Transport by Truck. Transportation and Marketing Programs. USDA Handbook No. 669

Asuming-Brempong, S. & Bruce, S. D., (2004). Responding to Economic Shocks in Ghana: the Agricultural Sector as a Social Safety Net, *Journal of Agricultural and Development Economics.*

Bani, R. J., Josiah, M. N. and Kra, E. Y. (2006). Postharvest Losses of Tomatoes in Transit. Agric Mech Asia Afr Lat *Am. Journal Code:* S0084B. Vol.37: NO.2. Pp.84-86

Baranska, M., Schütze, W., & Schulz, H. (2006). Determination of lycopene and β-carotene content in tomato fruits and related products: comparison of FT-Raman, ATRIR, and NIR spectroscopy. Analytical Chemistry, 78(24), 8456-8461.

Bauchet, G., & Causse, M. (2012). Genetic diversity in tomato (Solanum lycopersicum) and its wild relatives. . 8, 1 34-1 62.

Beckles, D. M. (2012). Factors affecting the postharvest soluble solids and sugar content of tomato (Solanum lycopersicum L.) fruit.

Beecher, B. R. (1998). Nutrient content of tomatoes and tomato products.

Bellwood-Howard, I., Häring, V., Karg, H., Roessler, R., Schlesinger, J., & Shakya, M.(2015). Characteristics of urban and peri-urban agriculture in West Africa: results of an exploratory survey conducted in Tamale (Ghana) and Ouagadougou (Burkina Faso) (Vol.1 63)

Bhagwati, J., & Panagariya, A. (2013). Why growth: How economic growth in India reduced poverty and the lessons for other developing countries. Hachette UK.

Bhowmik, D., Kumar, K. S., Paswan, S., & Srivastava, S. (2012). Tomato-a natural medicine and its health benefits. Journal of Pharmacognosy and Phytochemistry, 1 (1), 33-43.

Blench, R. M. (1999). Agriculture and the environment in northeastern Ghana: a comparison of high and medium population density areas. London. Research, 23(3), 25.

Bonsu, E. A. (2017). Effect of Neem (Azadiracta Indica A. Juss) Extract of Different Concentrations on the Management of Insect Pests of Garden Eggs (Solanum Melongena) in Birim Central Municipality in the Eastern Region of Ghana (Doctoral dissertation).

Briones, Roehlano M., (2013). Market Structure and Distribution of Benefits from Agricultural Exports.

Choudhury, B. (1975). Vegetable's national book trust of India New Delhi India.1975.

CIA (Central Intelligence Agency). (2017). The World Factbook, Field Listing: Exports – Commodities. CIA, Washington, DC. https://www.cia.gov/

Clark, R., Adhikari, P., Shrestha, J. & Acharya, B.P. (2000). Response of maize (Zea mays L.) hybrids to different levels of nitrogen. Archives of Agriculture and Environmental Science, 4(3), 295-299,

Clottey, V. A., Karbo, N., & Gyasi, K. O. (2009). The Tomato Industry In Northern Ghana: Production Constraints And Strategies To Improve Competitiveness.

D'Sousa, M.C. and M, Ingle. (1989). Effect of delayed cooling on the post storage flesh firmness of apples. J. Food Sci. Vol. 54: Pp 493.

Dawadi, D. R. and Sah, S. K. (2012). Growth and yield of hybrid maize (*Zea mays* L.) in relation to planting density and nitrogen levels during winter season in Nepal. *Tropical Agricultural Research,* 23 (3): 218-227.

Deng, W.T, Tang, L., Yin, D., Chen, C., Yu, D., & Han, W. (2015). Optimal design of plant canopy based on light interception: a case study with loquat. *Frontiers in plant science*, *10*, 364.

Dharani, N. (2011). Field guide to common trees & shrubs of East Africa. Penguin Random House South Africa.

Donkoh, S. A., Tachega, M., &Amowine, N. (2012). Estimating Technical Efficiency of Tomato Production in Northern Ghana. *American Journal of Experimental Agriculture,* 3(1): 56-75, 2012.

Dos, D. R. and Scarbook S. K. (2017). Growth and yield of hybrid maize (*Zea mays* L.) in relation to planting density and nitrogen levels during winter season in Nepal. *Tropical Agricultural Research,* 23 (3): 218-227

Eckert, J.W. and Eaks, J.L. (1989). Postharvest disorders and diseases of citrus fruit. Pages 179-260 in: The citrus industry. Vol. 5. Reuther, W. Calavan, E.E. and Carman, G.E. (Eds). University of California, Division of Agriculture and Natural Resources, Ock.

Ellis, W.O., Olympio, N.S., Mensah, E. P., Adu-Amankwa, A., Tetteh,Y. (1998). Postharvest problems of tomato production in Ghana - Field studies of some selected major Energy, Industry and Climate Protection (pp. 41 4-41 7).

Englberger, L., & Johnson, E. (2013). Traditional foods of the Pacific: Go Local, a case study in Pohnpei, Federated States of Micronesia.

Etebu, E., Nwauzoma, A. B., &Bawo, D. D. S. (2013). Postharvest spoilage of tomato Lycopersicon esculentum Mill.) and control strategies in Nigeria. *Journal of Biology,*

Fahad, S., Hussain, S., Saud, S., Hassan, S., Ihsan, Z., Shah, A. N., ... &Alghabari, F. (2016). Exogenously applied plant growth regulators enhance the morpho-physiological growth and yield of rice under high temperature. *Frontiers in Plant Science,* 7, 1 250.

FAO (1995). Food and Agriculture Organization of the United Nations Quarterly Bulletin of Statistics 8: 3-4. 1995.

FAO (2005). Food and Agricultural Organization Statistics Book on National Crop Production. Rome, Italy

FAO (Food and Agriculture Organization of the United Nations). (2017). FAOSTAT Database. http://faostat3.fao.org/

FAOSTAT. (2014). Food and Agricultural Organization Statistics Book on National Crop

FAOSTAT. (2015). Global production and trade of tomatoes FAO.

Filippone, P.T. (2006). Tomato and Health. From: (Heinz Institute of Nutritional Sciences.

Flore, J. A. (2011). Environmental and Physiological Regulation of Photosynthesis in tomatoes.

Food and Agriculture Organisation (FAO) (2015). FAOSTAT. Retrieved fromhttp://faostat3.fao.org/download/Q/QC/E.

Food and Agriculture Organization (2008). FAOSTAT. http://faostat.fao.org. (Online) fresh tomato and potato (Master's thesis, Institutt for biologi).

Fry, W. (2008). Phytophthora infestans: the plant (and R gene) destroyer. Molecular. ganoderma spp., on sclerotium rolfsiisacc and post-harvest tomato (Lycopersicon esculentum Mill.) fruits preservation. *Journal of Applied Sciences Research*, 6(11), 1 794 -1 800.

Gardner O.P., Sugri, I., Maalekuu, B. K., Gaveh, E., & Kusi, F. (2010). Sweet potato value chain analysis reveals opportunities for increased income and food security in Northern Ghana. *Advances in Agriculture*, *2016*.

Gleason, M. L., & Edmunds, B. A. (2005). Tomato diseases and disorders. Department of pathology. Iowa State University.

Hanssen, I. M., Lapidot, M., &Thomma, B. P. (2010).). Emerging viral diseases of tomato.

Harvey, J.M. and Harris, C.M. (1986). In-storage softening of kiwifruit: effects of delayed cooling.

Hering, E. M. (2013). Biology of the leaf miners. Springer Science & Business Media., 29 Jun 2013 - Science - 420 pages

Horna, D., Smale M., and Falck-Zepeda,J. (2006). Assessing the Potential Economic Impact of Genetically Modified Crops in Ghana: Tomato, Garden Egg, Cabbage and in processing tomatoes. Scientia Horticulture, 27, 189-198.

Huang, K.D, Ali, M. K., &Moniruzzaman, M. (2017). Effect of Stem Staking on Growth and Yield of Tomato (*Lycopersicon esculentum* L.). *Journal of Agroecology and Natural Resource Management*, *4*, 1-4.

Huang, Y., He, C., Shen, C., Guo, J., Mubeen, S., Yuan, J., & Yang, Z. (2017). Toxicity of cadmium and its health risks from leafy vegetable consumption. Food & function, 8(4).

Hurst, W. C. (2010). Harvest, Handling and Sanitation Commercial Tomato Production ICOUR (1995). Farmers Bulletin NO. 17 Ghana.

IDA. International Development Agency, Ghana: Accelerating Growth to Halve Poverty. http://www.worldbank.org/ida Feb 2007; 1-10.

Jaiswal, A.B., P.H. Gourkhede and S.H. Narale, (2018). Studies of different plant geometry on yield and quality of groundnut genotypes drought prone area of Marathwada region. *Int. J. Chem. Stud.,* 6: 312-316.

Jarosz, L. (2008). The city in the country: Growing alternative food networks in Metropolitan areas. *Journal of rural studies,* 24(3), 231 -244.

Jenkins J. A. (1948). The origin of the cultivated tomato. Economic Botany. Volume 2, Issue 4, pp 379–392

Kalloo, G. (Ed.). (2012). Genetic improvement of tomato (Vol. 1 4). Springer Science http://dx.doi.org/10.1007/978-3-642-84275-7

Kamara, U.T Malaviarachchi, M.A., K.M. Karunarathne and S.N. Jayawardane, (2016). Influence of plant density on yield of hybrid maize (Zea *mays* L.) under supplementary irrigation. *Journal of Agricultural Science*, 3 (2): 58- 66.

Khaddy, B. S. (2015). Effect of planting date and poultry manure on flower abortion, yield of tomatio.

Kitinoja, L. (2004). Small-Scale Marketing Strategies Manual. UC PTRIC Hort Series No. 21.

Kitinoja, L. and Gorny, J. (2009). Storage Practices and Structures. Postharvest Technology for Fruit & Vegetable Produce Marketers. Chapter 7. Pp 1.1 – 20.6

Knapp, S., & Peralta, I. E. (2016). The tomato (Solanum lycopersicum L., Solanaceae).

Konings, P. (1981). Peasantry and the State in Ghana, the Example of the VEA Irrigation Project in the Upper Region of Ghana. Leiden: African Studies Centre, Working Paper No. 5.

Korir, N. K., Diao, W., Tao, R., Li, X., Kayesh, E., Li, A., & Wang, S. (2014). Genetic). Genetic of Cereals and Oilseeds, 2 (1), 61 -65

Kwapata, M.B. (1990). Response of contrasting to, tomato cultivars to depth of applied mulch and irrigation frequency under hot dry tropical condition. Buttenl'orth-West India 68: 301-303. 1 of Cereals and Oilseeds, 2 (1), 61 -65.

Leander, D. M., Agyeman, D., Samuel, K. O., Kwadwo, O., Eric, D.,& Michael, O. (2019) Review on tomato (Solanum lycopersicum, L.) Improvement Programmes in Ghana. Glover B Lack of market worries Upper East tomato farmers. The Daily Graphic of 26 March, 2007a; 150007: 28.

Lee, J. M., Kubota, C., Tsao, S. J., Bie, Z., Echevarria, P. H., Morra, L., & Oda, M. (2010). Current status of vegetable grafting: Diffusion, grafting techniques, automation. Scientia.

Leke, W. N., Mignouna, D. B., Brown, J. K., &Kvarnheden, A. (201 5). Begomovirus diseases complex: emerging threat to vegetable production system of West and Central Africa

Lima, G. P. P., Vianello, F., Corrêa, C. R., Campos, R. A. D. S., &Borguini, M. G. (2014). Polyphenols in fruits and vegetables and its effect on human health. *Food and Nutrition.*

Loic, S. G.H, Assefa, W., Tesfaye, B., &Dessalegn, L. (2018). Influence of Inter-Intra Row Spacing on Yield Losses of Tomato Cultivars. *Ethiopian Journal of Agricultural Sciences*, *25*(2), 15-28.

Macdiarmid, J. I., Loe, J., Kyle, J., & McNeill, G. (2013). "It was an education in portion management. *Biodiversity and insect pests: key issues for sustainable management,* 72-84.

McErlich, A. F., &Boydston, R. A. (2014). Current state of weed management in organic medicine and its health benefits. *Journal of Pharmacognosy and Phytochemistry,* 1 (1),33-43.

Mehnaz, S., Kowalik, T., Reynolds, B., &Lazarovits, G. (2010). Growth promoting effects of corn (Zea mays) bacterial isolates under greenhouse and field conditions. Soil

Miller, P.M. (1977). Interaction of plastic, hay and grass mulches and meta-sodium on control of Pratylenchus penetrans in tomato. *J. of Nematology* 9: 350-351.

Ministry of Food and Agriculture (MoFA) (2013). Agriculture in Ghana: Facts and Figures. Retrieved from http://mofa.gov.gh/site/?page_id=6032

MoFA (2011). Agriculture in Ghana: Facts and Figures (2010). Statistics, Research and Information Directorate (SRID), Ministry of Food and Agriculture, Ghana.

MoFA, Agriculture in Ghana: Facts and Figures (2010). Statistics, Research and Information Directorate (SRID), Ministry of Food and Agriculture, Ghana. 2011.

MoFAIR Centre, (2008). Production Guide for Tomato, Ministry of Food and Agriculture.

Mrema, C. G. and Rolle, S. R. (2002). Status of the postharvest sector and its contribution to agricultural development and economic growth. 9th JIRCAS International Symposium – *Value Addition to Agricultural Product,* pp. 13-20.

OhlroggeB.G.,Winter and D. E. (2013). Row spacing and weed control timing affect yield of aerobic rice. *Field Crops Research*, *121*(2), 226-231.

Olufajo J. N. (2012). Soil survey report of the Niger Delta. Federal Government Action of the Niger Delta 158.

Onat, B., Bakal, H., Gulluoglu, L. and Arioglu, H. (2017). The effect of row spacing and plant density on yield and yield components of peanut grown as a double crop in Mediterranean environment in Turkey. *Turkish Journal of field crops*, 22(1): 71-80.

Orzolek, M.D., Bogash, M.S., Harsh, M. R., Lynn, F., Kime, L.F.,Jayson, K., Harper, J.K. (2006). Tomato Production. Agricultural Alternatives Pub.

Osemwegie, O. O., Oghenekaro, A. O., &Owolo, L. O. (2010). Effects of pulverized ganoderma spp., on sclerotium rolfsiisacc and post-harves(Lycopersicon esculentum Mill.) fruits preservation. *Journal of Applied Sciences Research*, 6(1 1), 1 794 -1 800.

Petrie, P. R., &Clingeleffer, P. R. (2005). Effects of temperature and light (before and after budburst) on inflorescence morphology and flower number of Chardonnay grapevines (Vitis vinifera L.). *Australian Journal of Grape and Wine Research*, 1 1 (1), 59-65.

Prajapati, K., & Modi, H. A. (2012). The importance of potassium in plant growth-a Quality of Selected Greenhouse Tomatoes (Solanum Lycopersicum) Varieties as Affected by Different Growing Media and Potting Bag Sizes (Doctoral dissertation, University of Ghana).

Quinn, LG. (1974). An evaluation of the method of mulching and staking tomato grown during rains in SalTIuri, Nigeria. *Horticulture Research* 13: 97-104

Rafiei, D. R., (2019). Effect of row spacing, plant population and nitrogen level on grain sorghum production under required tillage systems, MSc. Thesis. Oklahoma State University.

Raza, Y, R., Karkleliene, N.T., Susuki, M., Furukava, Y., (2019). Studies on plant spacing of peanut. Tech. Bull. Facult. Hortic. (Ghib University). 6, 164-150. review. *Indian Journal of Plant Sciences,* 1 (02), 1 77-1 86.

Robbins, J. and Moore, P. P. (1992). Fruit quality of stored fresh red raspberries after a delay in cooling. *HortTechnology,* Vol. 2(4): Pp468-470.

Robinson, J. Z., &Kolavalli, S. L. (2010). The Case of Tomato in Ghana: Marketing, Ghana Strategy Support Programme (GSSP). S.Naika, J. Van Lidt De Jeude, M. De Goffau, M. Hilmi, and B. Van Dam, Cultivation of tomato production, processing and marketing. Published by Digigrafi, Wageningen, Netherlands 1989.

Saeed, G.D, Kołton, A., Kęska, K., &Czernicka, M. (2011). Selection of Tomato and Cucumber Accessions for Waterlogging Sensitivity through Morpho-Physiological Assessment at an Early Vegetative Stage. *Agronomy*, *10*(10), 1490.

Sarwar, M. (2011). Effects of Zinc fertilizer application on the incidence of rice stem sciences, 1 065-1 082.

Shewfelt, R. L. (2014). Measuring quality and maturity. In Postharvest Handling (pp. 387).

Sinnaduiai, S. (1992). Vegetable cultivation, Accra Asempa publication, Accra. size". Experience of eating a healthy diet and barriers to long term dietary change. Appetite, 71, 41 1 -41 9.

Skrutvold, E. (2014). Effects of storage and heat treatment on metabolism and quality of fresh tomato and potato (Master's thesis, Institutt for biologi).

Sowley, E. N. K., &Damba, Y. (2013). Influence of staking and pruning on growth and Staking methods and stem pruning on yield and quality of summer tomato. *Bangladesh Journal of Agricultural Research,* 41 (3), 41 9-432.

Tambo, J.A. and Gbemu, T. (2010). Resource-use Efficiency in Tomato Production in the Technology Research, 2 (1 2), 1 03-1 07.

Tieman, D., Zhu, G., Resende, M. F., Lin, T., Nguyen, C., Bies, D., & Ikeda, H. (2017). A chemical genetic roadmap to improved tomato flavor. Science, 355(6323), 391 -394.

Trinklein, H. David. (2010). Growing home garden tomatoes. University of Missouri Extension: http:/extension.missouri.edu/p/G646.

UNCTAD. (2015). Commodity Profile-Tomatoes. http: www.unctad.info/ en/ Infocomm/AATomato/, Accesed 19th July,2015.

USDA-AMS (United States Department of Agriculture, Agricultural Marketing Service). (2017). Tomatoes. USDA-AMS, Washington, DC. http://www.agmrc.org/ commodities-products/vegetables/tomatoes.

Van der Linden, P. J., & Farrar, D. R. (2011). Forest and shade trees of Iowa. University of Iowa Press.

Weston, S. (2014). Influence of row spacing reduction on maize grain yield in regions with a short summer. *PesquisaAgropecuariaBrasileira*. 36(6): 861-869.

Winter, R. (2009). A consumer's dictionary of food additives: Descriptions in plain.

Yemane, R M., Maboko, M. M., Du Plooy, C. P., &Chiloane, S. (2017). Effect of plant population, fruit and stem pruning on yield and quality of hydroponically grown tomato. *African Journal of Agricultural Research*, *6*(22), 5144-5148.

Zhang, S. Q., Palta, J. A., & Chen, Y. L. (2019). Influence of spatial arrangement in maize on root growth and water use efficiency. *Plant and Soil*, *415*(1-2), 131-144.